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Mattias Lantz - Uppsala, RIKEN

in collaboration with

Lembit Sihver - Chalmers, Roanoke, Texas



RIKEN Nishina Center
for Accelerator-Based Science



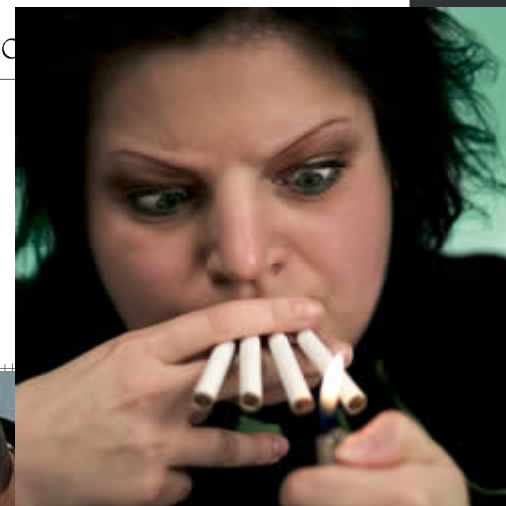
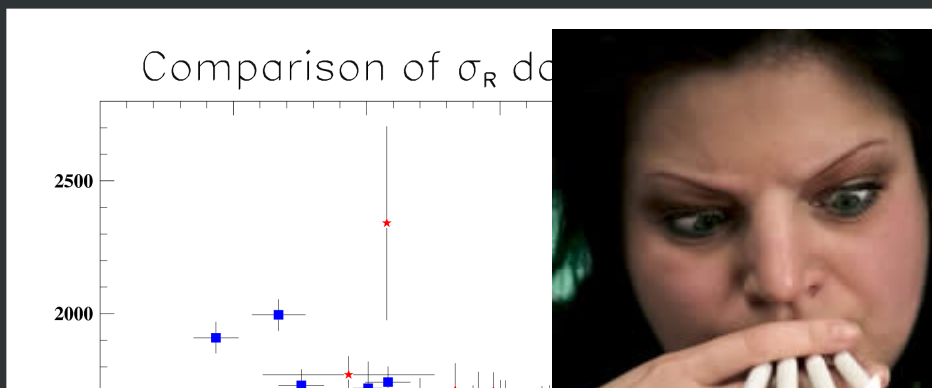
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A COMPILATION OF EXPERIMENTAL NUCLEAR DATA FOR TOTAL REACTION CROSS SECTIONS



Confessions of a nuclear data junkie



**Mattias Lantz – Uppsala University
RIKEN Nishina Center**

²⁰ Ne	²⁴ Mg	2.75	1124	111	z	[39]
²⁰ Ne	²⁴ Mg	2.75	1055	150	z	[39]
²⁰ Ne	²⁴ Mg	3.00	1163	121	z	[39]
²⁰ Ne	²⁴ Mg	3.50	1339	153	z	[39]
²⁰ Ne	²⁴ Mg	4.00	1527	104	z	[39]
²⁰ Ne	²⁴ Mg	4.25	1621	48	z	[39]
²⁰ Ne	²⁴ Mg	4.25	1693	242	z	[39]
²⁰ Ne	²⁴ Mg	5.25	1780	102	z	[39]
²⁰ Ne	²⁴ Mg	2.75	933.4	133.3	z	[217]
²⁰ Ne	²⁴ Mg	4.25	1498.3	214.0	z	[217]
²⁰ Ne	²⁷ Al	30	2130	120		[266]

²⁵ Ne	²⁸ Si	40.4	639	55		[424]
²⁵ Ne	²⁸ Si	44.615	2174	70		[422]
²⁵ Ne	²⁸ Si	48.92	2145	22		[258]
²⁵ Ne	²⁸ Si	53.808	2341	220		[422]



Confessions of a nuclear data junkie

- I am on the program...
- How could I fall for it?
- Status of my addiction
- How to find more of it
- How to find the good stuff
- Positive effects from the addiction?
- How to become free from the addiction
- A call for help



Confessions of a nuclear data junkie

- I am on the program...



The screenshot shows a Wikipedia article page for "Twelve-step program". At the top, there are navigation tabs for "article", "discussion", "edit this page", and "history". The article title is "Twelve-step program" and it is attributed to "From Wikipedia, the free encyclopedia". The main text describes the twelve-step program as a set of guiding principles for recovery from addiction or compulsion, originally proposed by Alcoholics Anonymous (AA). It mentions the book "Alcoholics Anonymous: The Story of How More Than One Hundred Men Have Recovered From Alcoholism" published in 1939. The text then lists the twelve steps, which are highlighted in brown boxes in the original image:

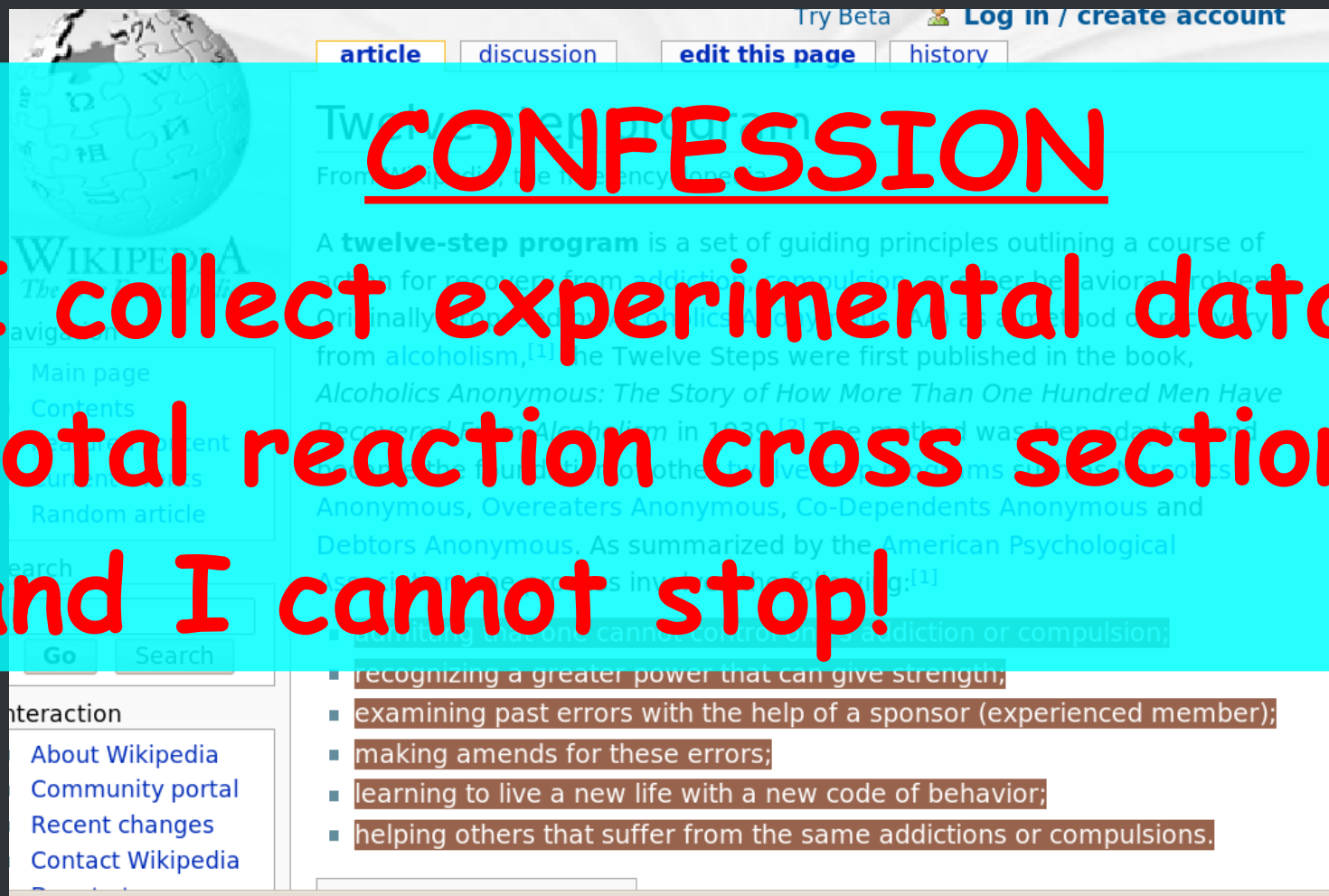
- admitting that one cannot control one's addiction or compulsion;
- recognizing a greater power that can give strength;
- examining past errors with the help of a sponsor (experienced member);
- making amends for these errors;
- learning to live a new life with a new code of behavior;
- helping others that suffer from the same addictions or compulsions.

On the left side of the screenshot, there is a sidebar with the Wikipedia logo, navigation links (Main page, Contents, Featured content, Current events, Random article), a search box with "Go" and "Search" buttons, and interaction links (About Wikipedia, Community portal, Recent changes, Contact Wikipedia).



Confessions of a nuclear data junkie

- I am on the program...



The image shows a screenshot of a Wikipedia article titled "Twelve-step program". The article text is partially obscured by a large red overlay. The overlay contains the word "CONFESSSION" (misspelled) underlined in red, followed by the text "I collect experimental data on total reaction cross sections, and I cannot stop!". The background text from the Wikipedia article includes: "A **twelve-step program** is a set of guiding principles outlining a course of action for recovery from addiction, compulsion, or other behavioral problem. Originally developed by Alcoholics Anonymous, a mutual aid group for people recovering from alcoholism,^[1] the Twelve Steps were first published in the book, *Alcoholics Anonymous: The Story of How More Than One Hundred Men Have Recovered From Alcoholism* in 1939.^[2] The method was then adopted by other groups, including the four main 12-step recovery programs: Alcoholics Anonymous, Overeaters Anonymous, Co-Dependents Anonymous and Debtors Anonymous. As summarized by the American Psychological Association, the program consists in: ^[1]

- recognizing a greater power that can give strength;
- examining past errors with the help of a sponsor (experienced member);
- making amends for these errors;
- learning to live a new life with a new code of behavior;
- helping others that suffer from the same addictions or compulsions.



How could I fall for it? (Background)



How could I fall for it? (Background)

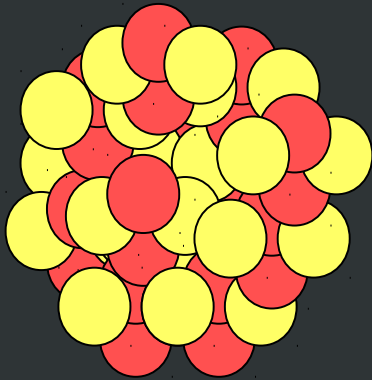
What is the total reaction cross section?



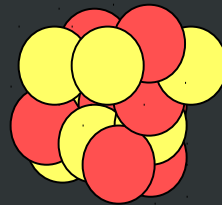
What happens when nuclei interact?

Ex: Fe ion incident on Oxygen

^{56}Fe

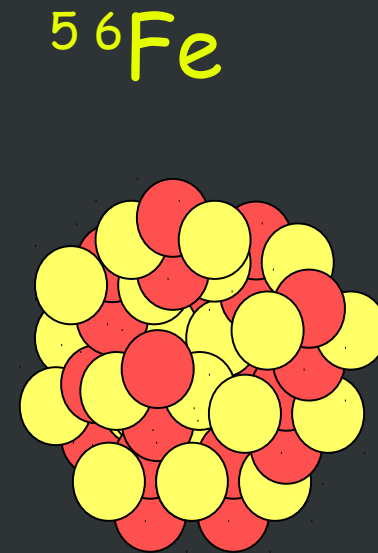
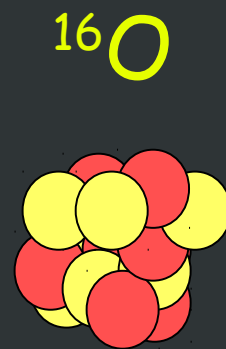
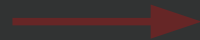
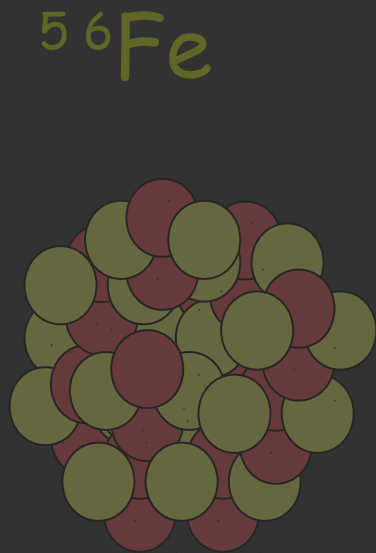


^{16}O



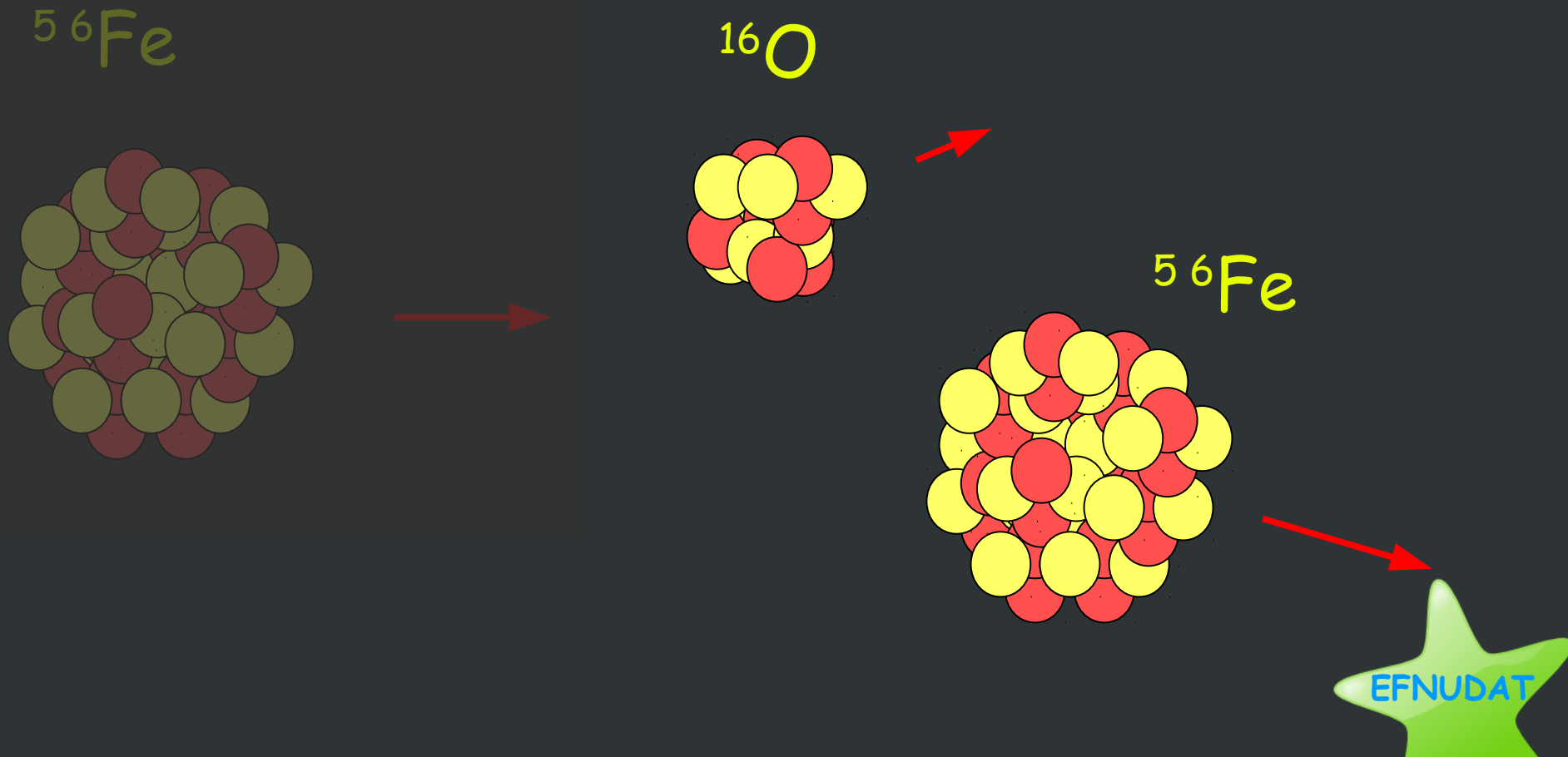
What happens when nuclei interact?

1: Nothing...



What happens when nuclei interact?

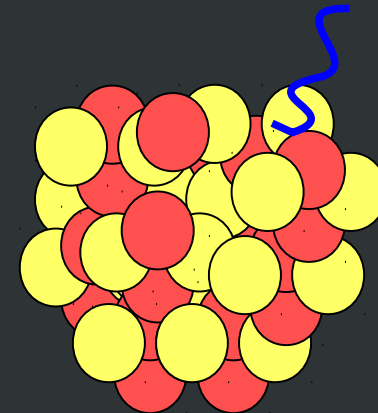
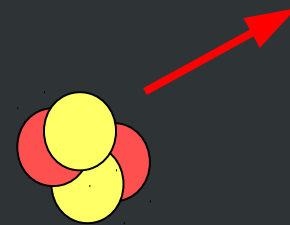
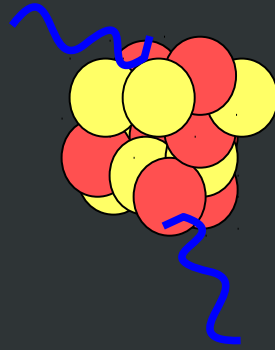
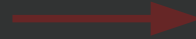
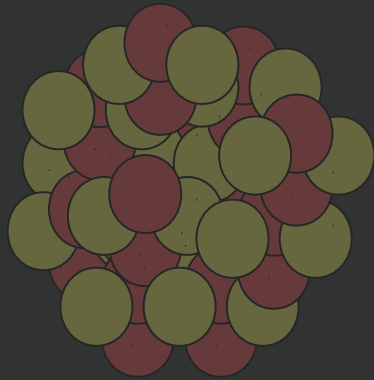
2: Elastic scattering σ_{EI}



What happens when nuclei interact?

3: Nonelastic interaction σ_R

^{56}Fe



What happens when nuclei interact?

3: Nonelastic interaction σ_R

Nuclear excitation

Nucleon knockout

Particle knockout

Nucleon exchange

Nucleon absorption

Spallation

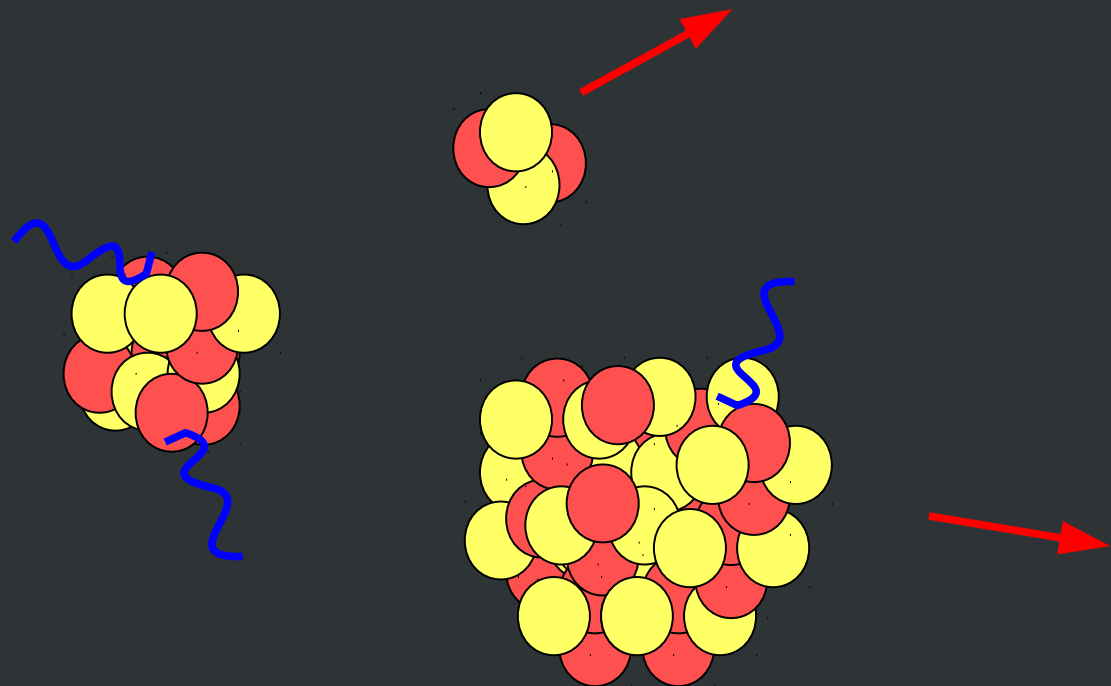
Fission

Fusion

Fragmentation

Spallation

...



What happens when nuclei interact?

3: Nonelastic interaction σ_R

Nuclear excitation
Nucleon knockout
Particle knockout
Nucleon exchange
Nucleon absorption
Spallation
Fission
Fusion
Fragmentation
Spallation
...

Each reaction has its individual cross section

The sum of all cross sections is the total reaction cross section



What happens when nuclei interact?

The total reaction cross section

=

The total probability for a
nonelastic reaction to occur

σ_R



What happens when nuclei interact?

The total reaction cross section

=

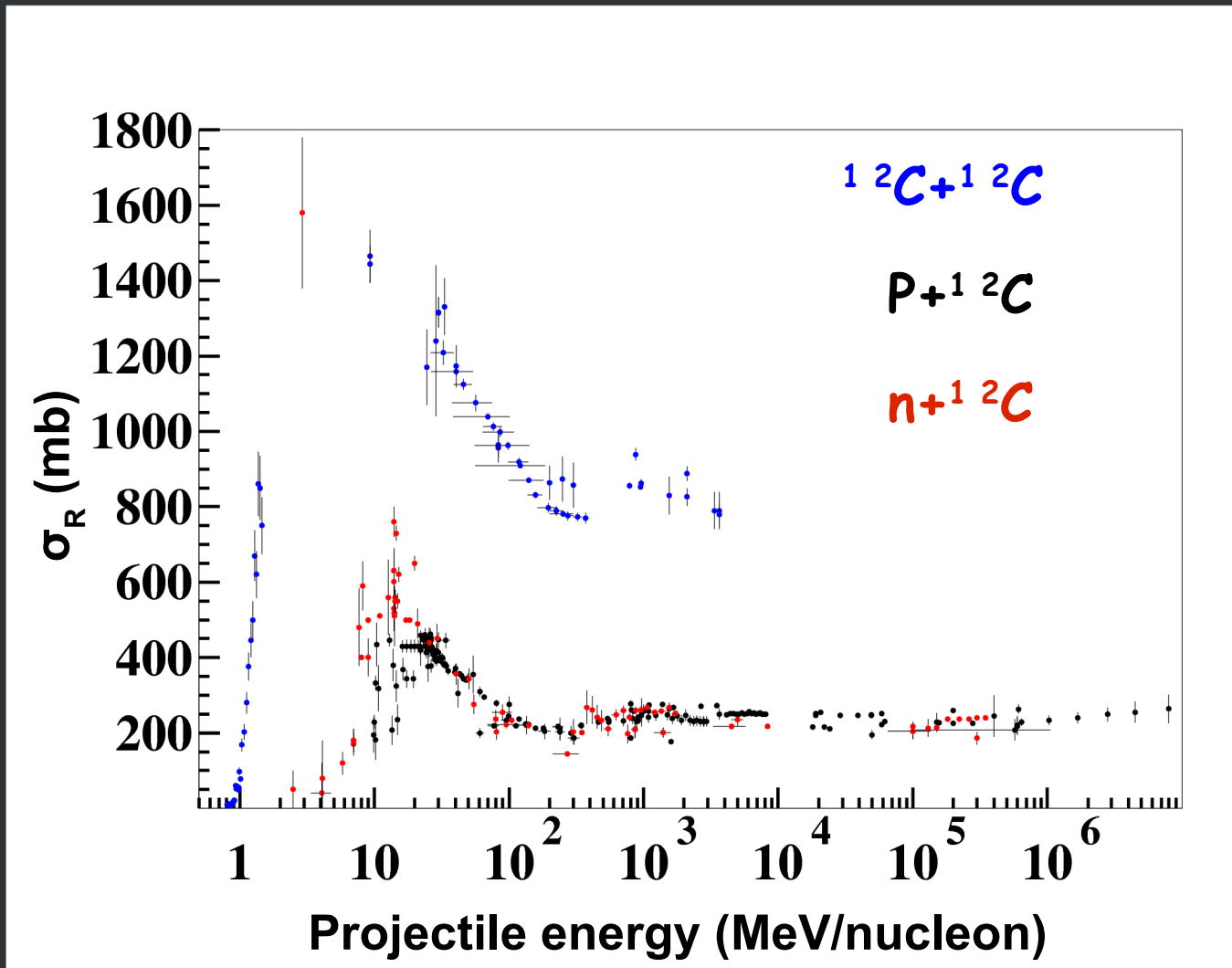
The total probability for a nonelastic reaction to occur

$$\sigma_{\text{Tot}} = \sigma_R + \sigma_{E1}$$



What happens when nuclei interact?

σ_R is energy dependent



Why bother? (the road to addiction...)

Total reaction cross sections can be used:

- To provide another constraint, besides angular distributions, in analyses of elastic scattering (Optical Model calculations...)
- To determine the sizes and matter distributions of the nuclei (exotic nuclei)

$$\sigma_R = \pi \cdot R_0^2 = \pi \cdot r_0^2 \left(A_P^{1/3} + A_T^{1/3} \right)^2$$



Why bother? (the road to addiction...)

Total reaction cross sections can be used:

- In a number of applications:
 - Radiation cancer treatment and dosimetry
 - Space radiation shielding and dosimetry
 - Cosmic radiation effects during interacting with matter (SEE/SEU)
 - Astrophysics (nucleosynthesis)
 - Transmutation of nuclear waste
 - Energy conversion



Why bother? (the road to addiction...)

Total reaction cross sections are used:

- In complex Monte Carlo codes
(FLUKA, GEANT, MCNPX, PHITS, ...):
 - Determine mean-free path before the first interaction in matter
 - Scaling factor for specific reactions
(p,n), (p,2pn), (p, α), ...



Why bother? (the road to addiction...)

A number of compilations available:

- Protons - Bauhoff (1986) → Carlson (1996), Barashenkov (1993)
- Exotic nuclei - Ozawa *et al.* (2001)
- Data bases
 - EXFOR
 - LANL (neutrons)



Why bother? (the road to addiction...)

A number of compilations available:

- Protons - Bauhoff (1986), $E < 1 \text{ GeV}$ /son (1996), Barashenkov (1993)
- Exotic nuclei - Ozawa *et al.* (2001)
- Data bases
 - EXFOR
 - LANL (neutrons)



Why bother? (the road to addiction...)

A number of compilations available:

- Protons - Bauhoff (1986), $E < 1$ GeV, Son (1996), Barashenkov (1993) **Inconsistencies...**
- Exotic nuclei - Ozawa *et al.* (2001)
- Data bases
 - EXFOR
 - LANL (neutrons)



Why bother? (the road to addiction...)

A number of compilations available:

- Protons - Bauhoff (1986), $E < 1$ GeV, Son (1996), Barashenkov (1993) Inconsistencies...
- Exotic nuclei - Ozawa *et al.* (2001) Limited nuclei
- Data bases
 - EXFOR
 - LANL (neutrons)



Why bother? (the road to addiction...)

A number of compilations available:

- Protons - Bauhoff (1986), $E < 1$ GeV, Ison (1996), Barashenkov (1993) Inconsistencies...
- Exotic nuclei - Ozawa *et al* Limited nuclei
- Data bases
 - EXFOR Very valuable resource, but limited, and somewhat complicated to use.
 - LANL (neutrons) Also some inconsistencies.



Why bother? (the road to addiction...)

Personal motivation:

- Need data for development of models, have collected (and measured) data since ~2000
- Noticed that some model makers are "lazy" or are not using the available data in a correct way
- Noticed that most model makers are not aware of all the available data (hard work!)



Why bother? (the road to addiction...)

Personal motivation:

Debtors Anonymous. As summarized by the American Psychological Association, the process involves the following:^[1]

- admitting that one cannot control one's addiction or compulsion;
- recognizing a greater power that can give strength;
- examining past errors with the help of a sponsor (experienced member);
- making amends for these errors;
- learning to live a new life with a new code of behavior;
- helping others that suffer from the same addictions or compulsions.

- Realized in 2009: I have a large collection of experimental data that many people seem to be unaware of, why not publish it?



Why bother? (the road to addiction...)

Personal motivation:

- 2009: Merged Lantz & Sihver data bases into one, following up references and citations
- Goal:
 - Submit for publication before end of 2010 (probably too optimistic)
 - Make data easily available for inclusion in EXFOR (have dialogue with IAEA)
 - (get done and move on with research...)



Status of my addiction

20 July 2010: 55 pages of tables, ~550 refs.

- σ_R data for:
 - p+A (~2100 data points)
 - n+A (~1100)
 - A+A (2400)
- Also other data of similar interest
 - σ_I A+A (~400)
 - σ_{CC} A+A (~900)
 - σ_{Tot} p+A, A+A (~300)



Status of my addiction

20 July 2010: 55 pages of tables, ~550 refs.

Proj	Target	Energy MeV/A	ΔE MeV/A	σ_R mb	$\Delta\sigma_R$ mb	Notes	Ref	Proj	Target	Energy MeV/A	ΔE MeV/A	σ_R mb	$\Delta\sigma_R$ mb	Notes	Ref
^{12}C	^{12}C	9.33		1465	70		[168]	^{12}C	^{28}Si	5.42		1440	60	s	[557]
^{12}C	^{12}C	9.33		1444	50		[430, 329]	^{12}C	Si	27	6	1700	40	r	[534]
^{12}C	^{12}C	24.42		1170	$^{+170}_{-100}$	z	[472]	^{12}C	Si	39	5	1555	45	r	[534]
^{12}C	^{12}C	28.7		1240	200	z	[364]	^{12}C	Si	70?				r	[347]
^{12}C	^{12}C	30		1315	40		[430, 328]	^{12}C	Si	3658		1130	80		[38]
^{12}C	^{12}C	30		1316	40		[329]	^{12}C	^{32}S	2100		1250	51	em	[355]
^{12}C	C	32.5	6.5	1209	32	x	[487]	^{12}C	^{40}Ca	83		1550	60		[328]
^{12}C	^{12}C	33.1		1331	75		[563]	^{12}C	^{40}Ca	83		1510	60		[329]
^{12}C	C	40.3	13.9	1159	11	x	[487]	^{12}C	Fe	200		1648	110		[329]
^{12}C	^{12}C	40.7		1173	56		[223]	^{12}C	Fe	250		1595	120		[329]
^{12}C	C	46.1	7.2	1125	15	x,d	[487]	^{12}C	Fe	300		1575	110		[329]
^{12}C	C	56.4	18.8	1076	22	x	[487]	^{12}C	^{54}Fe	30		2185	140		[329]
^{12}C	C	69.9	31.6	1039	9	x	[487]	^{12}C	^{54}Fe	83		1815	100		[328]
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^{12}C	^{12}C	83		957	39		[564]	^{12}C	^{56}Fe	83		1810	100		[328]
^{12}C	^{12}C	83		960	30		[430, 328]	^{12}C	^{56}Fe	83		1791	150		[329]
^{12}C	^{12}C	83		965	30		[329]	^{12}C	^{57}Fe	30		2296	160		[329]
^{12}C	C	86.3	22.8	998	13	x	[487]	^{12}C	^{57}Fe	83		1820	80		[328]
^{12}C	C	98.8	43.5	962	10	x	[487]	^{12}C	^{57}Fe	83		1867	100		[329]
^{12}C	C	118.4	20.2	919	11	x,d	[487]	^{12}C	Cu	29.78		2404	99		[451]
^{12}C	C	121.1	64.9	910	5	x	[487]	^{12}C	Cu	15	2.5	2200	350	z,r	[171]
^{12}C	C	139.8	40.1	870	5	x,d	[487]	^{12}C	Cu	25	1.7	2350	350	z,r	[171]
^{12}C	C	157.4	20.1	831	9	x,d	[487]	^{12}C	Cu	35		1750	250	z,r	[171]
^{12}C	C	195.5	33.2	797	13	x	[487]	^{12}C	Cu	45	1.0	1650	250	z,r	[171]
^{12}C	^{12}C	200		864	45		[329]	^{12}C	Cu	2100		1730	36	em	[355]
^{12}C	C	224.5	25.0	789	12	x	[487]	^{12}C	Cu	3658		1700	90		[38]
^{12}C	^{12}C	250		873	60		[329]	^{12}C	Cu	3700		2700	200	e	[185]
^{12}C	C	250.8	50.3	782	9	x	[487]	^{12}C	Cu	4500		2000	100	e	[31]
^{12}C	C	274.7	25.3	776	12	x,d	[487]	^{12}C	Zn	200		1747	110		[329]



How to find more of it

- Easy methods
 - Key word search: "total reaction cross section"
 - Author search
 - PACS numbers search
 - Check reference lists carefully
- Difficult methods
 - Find "strange" references (technical reports, conference proceedings, journals in Russian, Chinese...)
 - Talk with people
 - Use "Citing articles" function



How to find more of it

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Phys. Rev. 101, 324 (1956): Interactions of 380-Mev Alpha Particles in Nuclear Track Emulsion - Mozilla Firefox

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Phys. Rev. 101, 324–328

Interactions of 380-Mev Alpha Particles in Nuclear Track Emulsion

Abstract References Citing Articles (2) Page Images

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Dora Sherman Willoughby
Radiation Laboratory, University of California, Berkeley, California

Received 23 August 1955

A study has been made of stars produced by 380-Mev alpha particles in Ilford G.5 emulsion. The mean free path for star production is 18.4 ± 0.9 cm. The number of prongs per star varies from one to eight. The average number of prongs per star is 3.3. The striking feature of these stars is stripping, or splitting of the incident alpha particle. This is evident in the large number of two-prong stars in which both prongs emerge with high energy at small angles to the beam direction; in the presence of one-prong stars, in which the single prong is a fast proton or deuteron emerging in nearly the forward direction; and in the very narrow angular distribution of the fast prongs.


The star prongs have been divided into two groups, one group consisting almost entirely of cascade prongs, and the other consisting predominantly of evaporation prongs. The properties of the two groups of prongs are examined. It is found that the excitation produced by alpha particles is similar to that produced by protons of the same energy, but the cascade differs in important respects.

By observing the stars with prongs of energy lower than is necessary to escape the barrier of a heavy nucleus, one can identify 27% of the stars as originating in light nuclei. This places a lower limit on the number of events occurring in the gelatin.

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URL: <http://link.aps.org/doi/10.1103/PhysRev.101.324>
DOI: 10.1103/PhysRev.101.324

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How to find more of it

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Phys. Rev. 77, 54 (1950): The Heavy Nuclei of the Primary Cosmic Radiation - Mozilla Firefox

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Phys. Rev. 77, 54–70

The Heavy Nuclei of the Primary Cosmic Radiation

Abstract References **Citing Articles (139)** Page Images

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Journals


- Physical Review (33)**
- Physical Review C (32)**
- Il Nuovo Cimento (13)**
- Il Nuovo Cimento A (7)**
- Journal of Physics G Nuclear and Particle Physics (7)**
- Physical Review Letters (6)**
- Physical Review D (4)**
- Zeitschrift für Physik A Atoms and Nuclei (4)**

51. Possibility of simultaneous observation of nucleus fragment and γ -ray family in the stratosphere
Yasuo Niihori, Toru Shibata, Inacio M. Martin, Edison H. Shibuya, and Armando Turtelli
Phys. Rev. D **36**, 783 (1987)

52. Search for anomalous interaction mean free paths of charge, $2 \leq Z \leq 18$ projectile fragments in emulsions exposed to 1.8 A GeV40Ar ions
S. B. Beri, K. B. Bhalla, R. Bhanja, A. Bharti, V. S. Bhatia, G. Claesson, S. Garpman, S. K. Gupta, V. K. Gupta, N. Y. Herrstrom
Zeitschrift für Physik A Atomic Nuclei **327**, 431 (1987)

53. Pion production in inelastic and central nuclear collisions at high energy
M. Anikina, A. Golokhvastov, K. Iovchev, S. Khorozov, E. Kuznetzova, J. Lukstins, E. Okonov, T. Ostanevich, V. Toneev, G. Vardenga, L. Chkhaidze, T. Dzobava, M. Gaździcki, E. Skrzypczak, R. Szwed, and K. Gudima
Phys. Rev. C **33**, 895 (1986)

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Phys. Rev. 77, 54-70

The Heavy Nuclei of the Primary Cosmic Radiation

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Journals

- Physical Review (33)
- Physical Review C (32)
- Il Nuovo Cimento (2)
- Il Nuovo Cimento A (7)
- Journal of Physics G Nuclear and Particle Physics (1)
- Physical Review Letters (5)
- Physical Review (4)
- Zeitschrift für Physik A Atoms and Nuclei (4)

51. Possibility of simultaneous observation of nucleus fragment and γ -ray family in the stratosphere
Yasuo Niikori, Toru Shibata, Inao M. Marini, Edison H. Shibuya, and Armando Turtelli
Phys. Rev. D **36**, 783 (1987)

52. Search for α -nucleus interaction mean free paths of charge, $2 \leq Z \leq 18$ projectile fragments in emulsions exposed to ^{60}Co γ 40Ar ions
S. B. Bati, R. B. Bhalla, R. Bhanja, A. Bharti, V. S. Bhatia, G. Claesson, S. Garpman, S. K. Gupta, V. K. Gupta, N. Y. Herrstrom
Zeitschrift für Physik A Atomic Nuclei **327**, 431 (1987)

53. Pion production in inelastic and central nuclear collisions at high energy
M. Anikina, A. Golokhvastov, K. Iovchev, S. Khorozov, E. Kuznetzova, J. Lukstins, E. Okonov, T. Ostanevich, V. Toneev, G. Vardenga, L. Chkhaidze, T. Dzobava, M. Gaździcki, E. Skrzypczak, R. Szwed, and K. Gudima
Phys. Rev. C **33**, 895 (1986)

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Viewpoint: Proximity to understanding the cuprates
Trends: Rewiring for adaptation

NIGHTMARE: WHICH LINKS LEAD TO THE GOOD STUFF? WHICH ARE FROM A BAD CUT?

Done

How to find the good stuff

We are in a stage of quality control...

Proj	Target	Energy MeV/A	ΔE MeV/A	σ_R mb	$\Delta\sigma_R$ mb	Notes	Ref	Proj	Target	Energy MeV/A	ΔE MeV/A	σ_R mb	$\Delta\sigma_R$ mb	Notes	Ref
^{12}C	^{12}C	9.33		1465	70		[168]	^{12}C	^{28}Si	5.42		1440	60	s	[557]
^{12}C	^{12}C	9.33		1444	50		[430, 329]	^{12}C	Si	27	6	1700	40	r	[534]
^{12}C	^{12}C	24.42		1170	$^{+170}_{-100}$	z	[472]	^{12}C	Si	39	5	1555	45	r	[534]
^{12}C	^{12}C	28.7		1240	200	z	[364]	^{12}C	Si	70?				r	[347]
^{12}C	^{12}C	30		1315	40		[430, 328]	^{12}C	Si	3658		1130	80		[38]
^{12}C	^{12}C	30		1316	40		[329]	^{12}C	^{32}S	2100		1250	51	em	[355]
^{12}C	C	32.5	6.5	1209	32	x	[487]	^{12}C	^{40}Ca	83		1550	60		[328]
^{12}C	^{12}C	33.1		1331	75		[563]	^{12}C	^{40}Ca	83		1510	60		[329]
^{12}C	C	40.3	13.9	1159	11	x	[487]	^{12}C	Fe	200		1648	110		[329]
^{12}C	^{12}C	40.7		1173	56		[223]	^{12}C	Fe	250		1595	120		[329]
^{12}C	C	46.1	7.2	1125	15	x,d	[487]	^{12}C	Fe	300		1575	110		[329]
^{12}C	C	56.4	18.8	1076	22	x	[487]	^{12}C	^{54}Fe	30		2185	140		[329]
^{12}C	C	69.9	31.6	1039	9	x	[487]	^{12}C	^{54}Fe	83		1815	100		[328]
^{12}C	C	76.4	12.2	1013	12	x,d	[487]	^{12}C	^{54}Fe	83		1776	100		[329]
^{12}C	^{12}C	83		957	39		[564]	^{12}C	^{56}Fe	83		1810	100		[328]
^{12}C	^{12}C	83		960	30		[430, 328]	^{12}C	^{56}Fe	83		1791	150		[329]
^{12}C	^{12}C	83		965	30		[329]	^{12}C	^{57}Fe	30		2296	160		[329]
^{12}C	C	86.3	22.8	998	13	x	[487]	^{12}C	^{57}Fe	83		1820	80		[328]
^{12}C	C	98.8	43.5	962	10	x	[487]	^{12}C	^{57}Fe	83		1867	100		[329]
^{12}C	C	118.4	20.2	919	11	x,d	[487]	^{12}C	Cu	29.78		2404	99		[451]
^{12}C	C	121.1	64.9	910	5	x	[487]	^{12}C	Cu	15	2.5	2200	350	z,r	[171]
^{12}C	C	139.8	40.1	870	5	x,d	[487]	^{12}C	Cu	25	1.7	2350	350	z,r	[171]
^{12}C	C	157.4	20.1	831	9	x,d	[487]	^{12}C	Cu	35		1750	250	z,r	[171]
^{12}C	C	195.5	33.2	797	13	x	[487]	^{12}C	Cu	45	1.0	1650	250	z,r	[171]
^{12}C	^{12}C	200		864	45		[329]	^{12}C	Cu	2100		1730	36	em	[355]
^{12}C	C	224.5	25.0	789	12	x	[487]	^{12}C	Cu	3658		1700	90		[38]
^{12}C	^{12}C	250		873	60		[329]	^{12}C	Cu	3700		2700	200	e	[185]
^{12}C	C	250.8	50.3	782	9	x	[487]	^{12}C	Cu	4500		2000	100	e	[31]
^{12}C	C	274.7	25.3	776	12	x,d	[487]	^{12}C	Zn	200		1747	110		[329]



How to find the good stuff

We are in a stage of quality control...

Proj	Target	Energy MeV/A	ΔE MeV/A	σ_R mb	$\Delta\sigma_R$ mb	Notes	Ref	Proj	Target	Energy MeV/A	ΔE MeV/A	σ_R mb	$\Delta\sigma_R$ mb	Notes	Ref
^{12}C	^{12}C	9.33		1465	70		[168]	^{12}C	^{28}Si	5.42		1440	60	s	[557]
^{12}C	^{12}C	9.33		1444	50		[430, 329]	^{12}C	Si	27	6	1700	40	r	[534]
^{12}C	^{12}C	24.42		1170	+170		[472]	^{12}C	Si	39	5	1555	45	r	[534]
^{12}C	^{12}C	28.7		1315	40		[430, 328]	^{12}C	Si	70?				r	[347]
^{12}C	^{12}C	30		1316	40		[329]	^{12}C	Si	3658		1130	80		[38]
^{12}C	^{12}C	30		1316	40		[329]	^{12}C	^{32}S	2100		1250	51	em	[355]
^{12}C	C	32.5	6.5	1209	35		[430, 328]	^{12}C	C	83		1550	60		[328]
^{12}C	^{12}C	33.1		1331	75		[563]	^{12}C	^{40}Ca	83		1510	60		[329]
^{12}C	C	40.3	13.9	1159	11	x	[487]	^{12}C	Fe	200		1648	110		[329]
^{12}C	^{12}C	40.7		1173	56		[223]	^{12}C	Fe	250		1595	120		[329]
^{12}C	C	46.1	7.2	1125	15	x,d	[487]	^{12}C	Fe	300		1575	110		[329]
^{12}C	C	56.4	18.8	1076	22	x	[487]	^{12}C	^{54}Fe	30		2185	140		[329]
^{12}C	C	69.9	31.6	1039	9	x	[487]	^{12}C	^{54}Fe	83		1815	100		[328]
^{12}C	C	76.4	12.2	1013	12	x,d	[487]	^{12}C	^{54}Fe	83		1776	100		[329]
^{12}C	^{12}C	83		957	39		[564]	^{12}C	^{56}Fe	83		1810	100		[328]
^{12}C	^{12}C	83		960	30		[430, 328]	^{12}C	^{56}Fe	83		1791	150		[329]
^{12}C	^{12}C	83		965	30		[329]	^{12}C	^{57}Fe	30		2296	160		[329]
^{12}C	C	86.3	22.8	998	13	x	[487]	^{12}C	^{57}Fe	83		1820	80		[328]
^{12}C	C	98.8	43.5	962	10	x	[487]	^{12}C	^{57}Fe	83		1867	100		[329]
^{12}C	C	118.4	20.2	919	11	x,d	[487]	^{12}C	Cu	29.78		2404	99		[451]
^{12}C	C	121.1	64.9	910	5	x	[487]	^{12}C	Cu	15	2.5	2200	350	z,r	[171]
^{12}C	C	139.8	40.1	870	5	x,d	[487]	^{12}C	Cu	25	1.7	2350	350	z,r	[171]
^{12}C	C	157.4	20.1	831	9	x,d	[487]	^{12}C	Cu	35		1750	250	z,r	[171]
^{12}C	C	195.5	33.2	797	13	x	[487]	^{12}C	Cu	45	1.0	1650	250	z,r	[171]
^{12}C	^{12}C	200		864	45		[329]	^{12}C	Cu	2100		1730	36	em	[355]
^{12}C	C	224.5	25.0	789	12	x	[487]	^{12}C	Cu	3658		1700	90		[38]
^{12}C	^{12}C	250		873	60		[329]	^{12}C	Cu	3700		2700	200	e	[185]
^{12}C	C	250.8	50.3	782	9	x	[487]	^{12}C	Cu	4500		2000	100	e	[31]
^{12}C	C	274.7	25.3	776	12	x,d	[487]	^{12}C	Zn	200		1747	110		[329]

Isotopically enriched or natural composition?



How to find the good stuff

We are in a stage of quality control...

Proj	Target	Energy MeV/A	ΔE MeV/A	σ_R mb	$\Delta\sigma_R$ mb	Notes	Ref
^{12}C	^{12}C	9.33		1465	70		[168]
^{12}C	^{12}C	9.33		1444	50		[430, 329]
^{12}C	^{12}C	24.42		1176	170		[475]
^{12}C	^{12}C	28.7		1200	100		[430, 328]
^{12}C	^{12}C	30		1315	40		[430, 328]
^{12}C	^{12}C	30		1316	40		[430, 328]
^{12}C	C	32.5	6.5	1209	32	x	[487]
^{12}C	^{12}C	33.1		1331	75		[563]
^{12}C	C	40.3	13.9	1159	11	x	[487]
^{12}C	^{12}C	40.7		1173	56		[223]
^{12}C	C	46.1	7.2	1125	15	x,d	[487]
^{12}C	C	56.4	18.8	1076	22	x	[487]
^{12}C	C	69.9	31.6	1039	9	x	[487]
^{12}C	C	76.4	12.2	1013	12	x,d	[487]
^{12}C	^{12}C	83		957	39		[564]
^{12}C	^{12}C	83		960	30		[430, 328]
^{12}C	^{12}C	83		965	30		[329]
^{12}C	C	86.3	22.8	998	13	x	[487]
^{12}C	C	98.8	43.5	962	10	x	[487]
^{12}C	C	118.4	20.2	919	11	x,d	[487]
^{12}C	C	121.1	64.9	910	5	x	[487]
^{12}C	C	139.8	40.1	870	5	x,d	[487]
^{12}C	C	157.4	20.1	831	9	x,d	[487]
^{12}C	C	195.5	33.2	797	13	x	[487]
^{12}C	^{12}C	200		864	45		[329]
^{12}C	C	224.5	25.0	789	12	x	[487]
^{12}C	^{12}C	250		873	60		[329]
^{12}C	C	250.8	50.3	782	9	x	[487]
^{12}C	C	274.7	25.3	776	12	x,d	[487]

Which energy?
No errors given

Proj	Target	Energy MeV/A	ΔE MeV/A	σ_R mb	$\Delta\sigma_R$ mb	Notes	Ref
^{12}C	^{28}Si	5.42		1440	60	s	[557]
^{12}C	Si	27	6	1700	40	r	[534]
^{12}C	Si	39	5	1555	45	r	[534]
^{12}C	Si	70?				r	[347]
^{12}C	Si	3658		1130	80		[38]
^{12}C	^{32}S	2100		1250	51	em	[355]
^{12}C	^{40}Ca	83		1550	60		[328]
^{12}C	^{40}Ca	83		1510	60		[329]
^{12}C	Fe	200		1648	110		[329]
^{12}C	Fe	250		1595	120		[329]
^{12}C	Fe	300		1575	110		[329]
^{12}C	^{54}Fe	30		2185	140		[329]
^{12}C	^{54}Fe	83		1815	100		[328]
^{12}C	^{54}Fe	83		1776	100		[329]
^{12}C	^{56}Fe	83		1810	100		[328]
^{12}C	^{56}Fe	83		1791	150		[329]
^{12}C	^{57}Fe	30		2296	160		[329]
^{12}C	^{57}Fe	83		1820	80		[328]
^{12}C	^{57}Fe	83		1867	100		[329]
^{12}C	Cu	29.78		2404	99		[451]
^{12}C	Cu	15	2.5	2200	350	z,r	[171]
^{12}C	Cu	25	1.7	2350	350	z,r	[171]
^{12}C	Cu	35		1750	250	z,r	[171]
^{12}C	Cu	45	1.0	1650	250	z,r	[171]
^{12}C	Cu	2100		1730	36	em	[355]
^{12}C	Cu	3658		1700	90		[38]
^{12}C	Cu	3700		2700	200	e	[185]
^{12}C	Cu	4500		2000	100	e	[31]
^{12}C	Zn	200		1747	110		[329]



How to find the good stuff

We are in a stage of quality control...

Proj	Target	Energy MeV/A	ΔE MeV/A	σ_R mb	$\Delta\sigma_R$ mb	Notes	Ref	Proj	Target	Energy MeV/A	ΔE MeV/A	σ_R mb	$\Delta\sigma_R$ mb	Notes	Ref
^{12}C	^{12}C	9.33		1465	70		[168]	^{12}C	^{28}Si	5.42		1440	60	s	[557]
^{12}C	^{12}C	9.33		1465	5		[329]	^{12}C	^{28}Si	36		1700	40	r	[534]
^{12}C	^{12}C	24.42		1170	+170 -100	z	[472]	^{12}C	^{28}Si	39	5	1555	45	r	[534]
^{12}C	^{12}C	28.7		1240	200		[364]	^{12}C	^{28}Si	70?		1130	80	r	[347]
^{12}C	^{12}C	30		1315	40		[430, 328]	^{12}C	^{28}Si	3658		1130	80		[38]
^{12}C	^{12}C	30		1316	40		[329]	^{12}C	^{32}S	2100		1250	51	em	[355]
^{12}C	C	32.5		1316	40		[329]	^{12}C	^{40}Ca	83		1510	60		[328]
^{12}C	^{12}C	33.1		1331	75		[53]	^{12}C	^{40}Ca	83		1510	60		[329]
^{12}C	C	40.3	13.9	1159	11	x	[487]	^{12}C	Fe	200		1648	110		[329]
^{12}C	^{12}C	40.7		1173	56		[223]	^{12}C	Fe	250		1595	120		[329]
^{12}C	C	46.1	7.2	1125	15	x,d	[487]	^{12}C	Fe	300		1575	110		[329]
^{12}C	C	56.4	18.8	1076	22	x	[487]	^{12}C	^{54}Fe	30		2185	140		[329]
^{12}C	C	69.9	31.6	1039	9	x	[487]	^{12}C	^{54}Fe	83		1815	100		[328]
^{12}C	C	76.4	12.2	1013	12	x,d	[487]	^{12}C	^{54}Fe	83		1776	100		[329]
^{12}C	^{12}C	83		957	39		[564]	^{12}C	^{56}Fe	83		1810	100		[328]
^{12}C	^{12}C	83		960	30		[430, 328]	^{12}C	^{56}Fe	83		1791	150		[329]
^{12}C	^{12}C	83		965	30		[329]	^{12}C	^{57}Fe	30		2296	160		[329]
^{12}C	C	86.3	22.8	998	13	x	[487]	^{12}C	^{57}Fe	83		1820	80		[328]
^{12}C	C	98.8	43.5	962	10	x	[487]	^{12}C	^{57}Fe	83		1867	100		[329]
^{12}C	C	118.4	20.2	919	11	x,d	[487]	^{12}C	Cu	29.78		2404	99		[451]
^{12}C	C	121.1	64.9	910	5	x	[487]	^{12}C	Cu	15	2.5	2200	350	z,r	[171]
^{12}C	C	139.8	40.1	870	5	x,d	[487]	^{12}C	Cu	25	1.7	2350	350	z,r	[171]
^{12}C	C	157.4	20.1	831	9	x,d	[487]	^{12}C	Cu	35		1750	250	z,r	[171]
^{12}C	C	195.5	33.2	797	13	x	[487]	^{12}C	Cu	45	1.0	1650	250	z,r	[171]
^{12}C	^{12}C	200		864	45		[329]	^{12}C	Cu	2100		1730	36	em	[355]
^{12}C	C	224.5	25.0	789	12	x	[487]	^{12}C	Cu	3658		1700	90		[38]
^{12}C	^{12}C	250		873	60		[329]	^{12}C	Cu	3700		2700	200	e	[185]
^{12}C	C	250.8	50.3	782	9	x	[487]	^{12}C	Cu	4500		2000	100	e	[31]
^{12}C	C	274.7	25.3	776	12	x,d	[487]	^{12}C	Zn	200		1747	110		[329]

s = Sum of Differences method

em = emulsion technique

Trustworthy experimental methods?



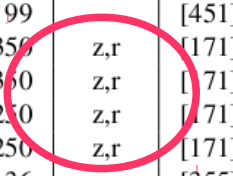
How to find the good stuff

We are in a stage of quality control...

Proj	Target	Energy MeV/A	ΔE MeV/A	σ_R mb	$\Delta\sigma_R$ mb	Notes	Ref	Proj	Target	Energy MeV/A	ΔE MeV/A	σ_R mb	$\Delta\sigma_R$ mb	Notes	Ref
^{12}C	^{12}C	9.33		1465	70		[168]	^{12}C	^{28}Si	5.42		1440	60	s	[557]
^{12}C	^{12}C	9.33		1444	50		[430, 329]	^{12}C	Si	27	6	1700	40	r	[534]
^{12}C	^{12}C	24.42		1170	$^{+170}_{-100}$	z	[472]	^{12}C	Si	39	5	1555	45	r	[534]
^{12}C	^{12}C	28.7		1240	200	z	[364]	^{12}C	Si	70?				r	[347]
^{12}C	^{12}C	30		1315	40		[430, 328]	^{12}C	Si	3658		1130	80		[38]
^{12}C	^{12}C	30		1316	40		[329]	^{12}C	^{32}S	2100		1250	51	em	[355]
^{12}C	C	32.5	6.5	1209	32	x	[487]	^{12}C	^{40}Ca	83		1550	60		[328]
^{12}C	^{12}C	33.1		1331	75		[563]	^{12}C	^{40}Ca	83		1510	60		[329]
^{12}C	C	40.3	13.9	1159	11	x	[487]	^{12}C	Fe	200		1648	110		[329]
^{12}C	^{12}C	40.7		1173	56		[223]	^{12}C	Fe	250		1595	120		[329]
^{12}C	C	46.1	7.2	1125	15	x,d	[487]	^{12}C	Fe	300		1575	110		[329]
^{12}C	C	56.4	18.8	1076	22	x	[487]	^{12}C	^{54}Fe	30		2185	140		[329]
^{12}C	C	69.9	31.6	1039	9	x	[487]	^{12}C	^{54}Fe	83		1815	100		[328]
^{12}C	C	76.4	12.2	1013	12	x,d	[487]	^{12}C	^{54}Fe	83		1776	100		[329]
^{12}C	^{12}C	83		957	39		[504]	^{12}C	^{54}Fe	83		1710	100		[328]
^{12}C	^{12}C	83		960	30		[430, 328]	^{12}C	^{56}Fe	83		1791	150		[329]
^{12}C	^{12}C	83		965	30		[329]	^{12}C	^{57}Fe	83		2206	160		[329]
^{12}C	C	86.3	22.8	998	13	x	[487]	^{12}C	^{57}Fe	83		1880	100		[329]
^{12}C	C	98.8	43.5	962	10	x	[487]	^{12}C	Cu	29.78		2404	99		[451]
^{12}C	C	118.4	20.2	919	11	x,d	[487]	^{12}C	Cu	15	2.5	2200	350	z,r	[171]
^{12}C	C	121.1	64.9	910	5	x	[487]	^{12}C	Cu	25	1.7	2350	350	z,r	[171]
^{12}C	C	139.8	40.1	870	5	x,d	[487]	^{12}C	Cu	35		1750	250	z,r	[171]
^{12}C	C	157.4	20.1	831	9	x,d	[487]	^{12}C	Cu	45	1.0	1650	250	z,r	[171]
^{12}C	C	195.5	33.2	797	13	x	[487]	^{12}C	Cu	2100		1730	36	em	[355]
^{12}C	^{12}C	200		864	45		[329]	^{12}C	Cu	3658		1700	90		[38]
^{12}C	C	224.5	25.0	789	12	x	[487]	^{12}C	Cu	3700		2700	200	e	[185]
^{12}C	^{12}C	250		873	60		[329]	^{12}C	Cu	4500		2000	100	e	[31]
^{12}C	C	250.8	50.3	782	9	x	[487]	^{12}C	Zn	200		1747	110		[329]
^{12}C	C	274.7	25.3	776	12	x,d	[487]								

r = read data from plots

z = sum of different reactions



How to find the good stuff

We are in a stage of quality control...

Proj	Target	Energy MeV/A	ΔE MeV/A	σ_R mb	$\Delta\sigma_R$ mb	Notes	Ref	Proj	Target	Energy MeV/A	ΔE MeV/A	σ_R mb	$\Delta\sigma_R$ mb	Notes	Ref
^{12}C	^{12}C	9.33		1465	70		[168]	^{12}C	^{28}Si	5.42		1440	60	s	[557]
^{12}C	^{12}C	9.33		1444	50		[430, 329]	^{12}C	Si	27	6	1700	40	r	[534]
^{12}C	^{12}C	24.42		1170	$^{+170}_{-100}$	z	[472]	^{12}C	Si	39	5	1555	45	r	[534]
^{12}C	^{12}C	28.7		1240	200	z	[364]	^{12}C	Si	70?				r	[347]
^{12}C	^{12}C	30		1315	40		[430, 328]	^{12}C	Si	3658		1130	80		[33]
^{12}C	^{12}C	30		1316	40		[329]	^{12}C	^{32}S	2100		1250	51	em	[355]
^{12}C	C	32.5	6.5	1209	32	x	[487]	^{12}C	^{40}Ca	83		1550	60		[328]
^{12}C	^{12}C	33.1		1331	75		[563]	^{12}C	^{40}Ca	83		1510	60		[329]
^{12}C	C	40.3	13.9	1159	11	x	[487]	^{12}C	Fe	200		1648	110		[329]
^{12}C	^{12}C	40.7		1173	56		[223]	^{12}C	Fe	250		1595	120		[329]
^{12}C	C	46.1	7.2	1125	15	x,d	[487]	^{12}C	Fe	300		1575	110		[329]
^{12}C	C	56.4	18.8	1076	22	x	[487]	^{12}C	^{54}Fe	30		2185	140		[329]
^{12}C	C	69.9	31.6	1039	9	x	[487]	^{12}C	^{54}Fe	83		1815	100		[328]
^{12}C	C	76.4	12.2	1013	12	x,d	[487]	^{12}C	^{54}Fe	83		1776	100		[329]
^{12}C	^{12}C	83		957	39		[563]	^{12}C	^{54}Fe	83		1791	150		[328]
^{12}C	^{12}C	83		960	30		[430, 328]	^{12}C	^{56}Fe	83		1791	150		[329]
^{12}C	^{12}C	83		965	30		[329]	^{12}C	^{57}Fe	30		2296	100		[329]
^{12}C	C	86.3	22.8	998	13	x	[487]	^{12}C	^{57}Fe	83		1867	100		[328]
^{12}C	C	98.8	43.5	962	10	x	[487]	^{12}C	^{57}Fe	83		1867	100		[329]
^{12}C	C	118.4	20.2	919	11	x,d	[487]	^{12}C	Cu	29.78		2404	99		[451]
^{12}C	C	121.1	64.9	910	5	x	[487]	^{12}C	Cu	15	2.5	2200	350	z,r	[171]
^{12}C	C	139.8	40.1	870	5	x,d	[487]	^{12}C	Cu	25	1.7	2350	350	z,r	[171]
^{12}C	C	157.4	20.1	831	9	x,d	[487]	^{12}C	Cu	35		1750	250	z,r	[171]
^{12}C	C	195.5	33.2	797	13	x	[487]	^{12}C	Cu	45	1.0	1650	250	z,r	[171]
^{12}C	^{12}C	200		864	45		[329]	^{12}C	Cu	2100		1730	36	em	[355]
^{12}C	C	224.5	25.0	789	12	x	[487]	^{12}C	Cu	3658		1700	90		[38]
^{12}C	^{12}C	250		873	60		[329]	^{12}C	Cu	3700		2700	200	e	[185]
^{12}C	C	250.8	50.3	782	9	x	[487]	^{12}C	Cu	4500		2000	100	e	[31]
^{12}C	C	274.7	25.3	776	12	x,d	[487]	^{12}C	Zn	200		1747	110		[329]

Do we need more columns?
(Laboratory, Exp. method)

How to find the good stuff

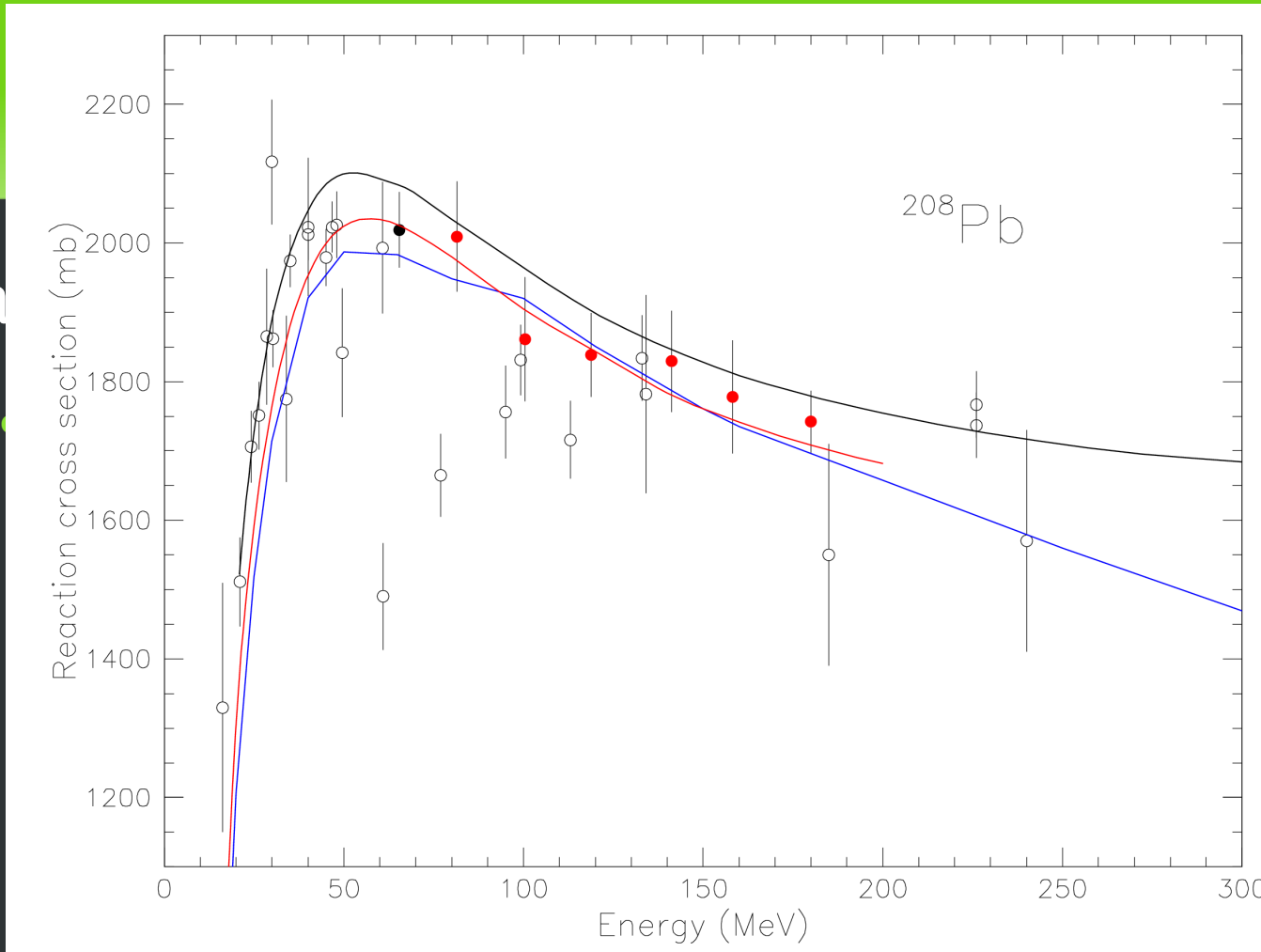
- Quality check of all references → decrease the list
 - Which kind of experimental methods should be included?
 - Direct measurements
 - Summed or integrated partial cross sections
 - Emulsion and solid state track detectors
 - Model dependent derivations from other variables
 - Will set threshold based on quality of experimental method, not on quality of result
 - Maybe good reasons why some data are forgotten...?



Ho

stuff

• Quality



the list

and be

s

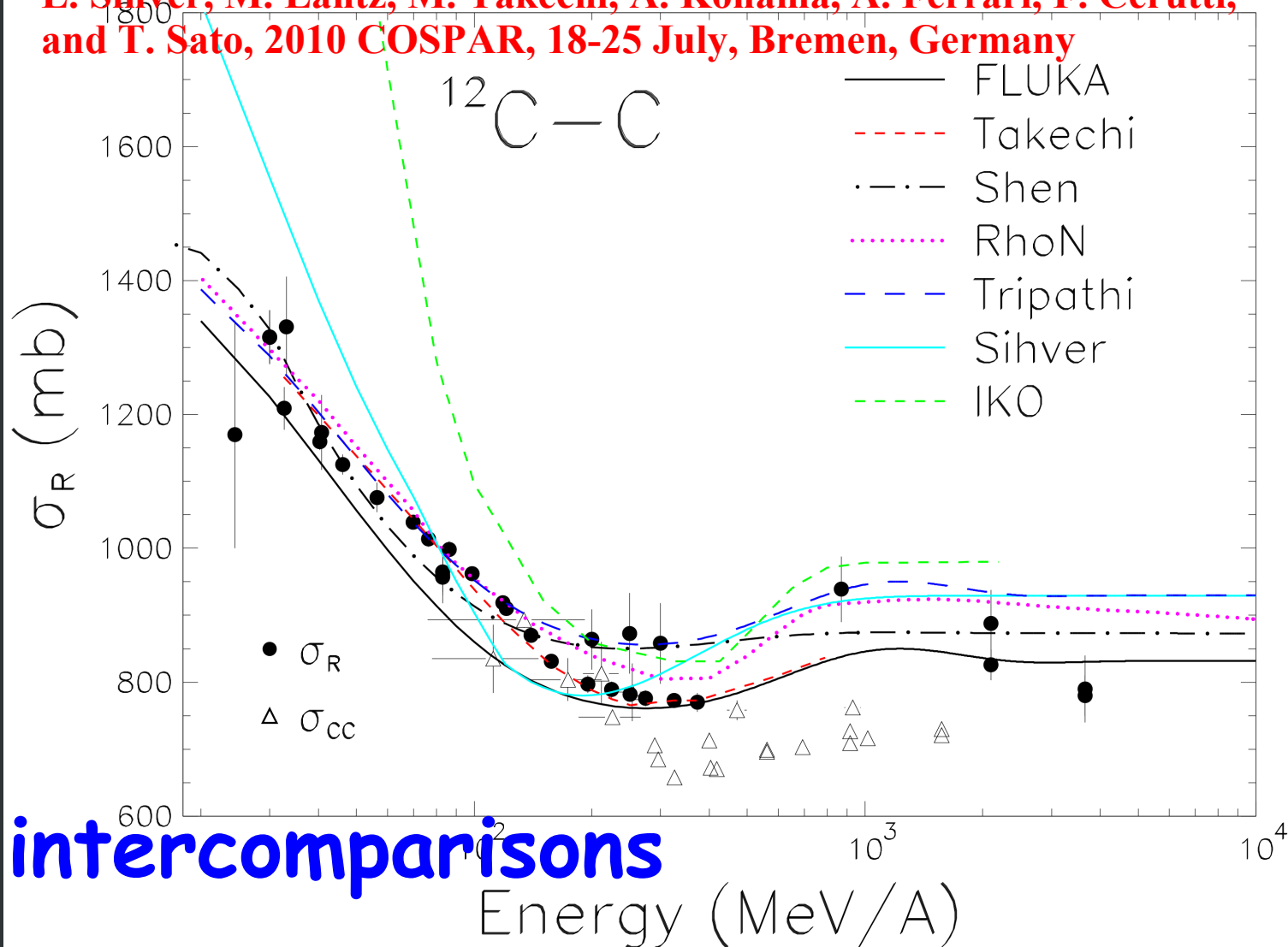
variables

- Will set threshold based on quality of experimental method, not on quality of result
- Maybe good reasons why some data are forgotten...?



Positive effects from the addition

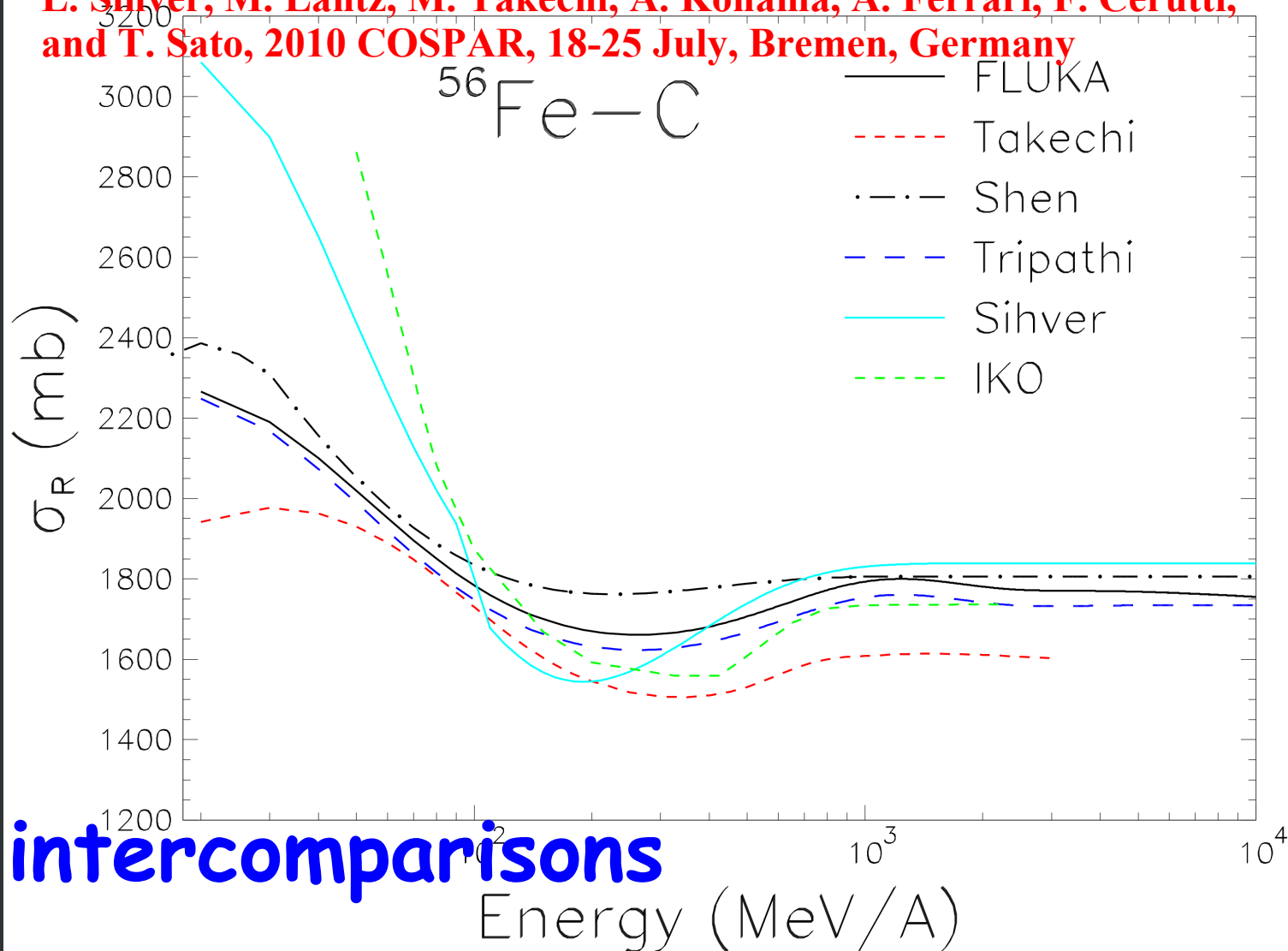
L. Sihver, M. Lantz, M. Takechi, A. Kohama, A. Ferrari, F. Cerutti, and T. Sato, 2010 COSPAR, 18-25 July, Bremen, Germany



Code intercomparisons

Positive effects from the addition

L. Sihver, M. Lantz, M. Takechi, A. Kohama, A. Ferrari, F. Cerutti,
and T. Sato, 2010 COSPAR, 18-25 July, Bremen, Germany

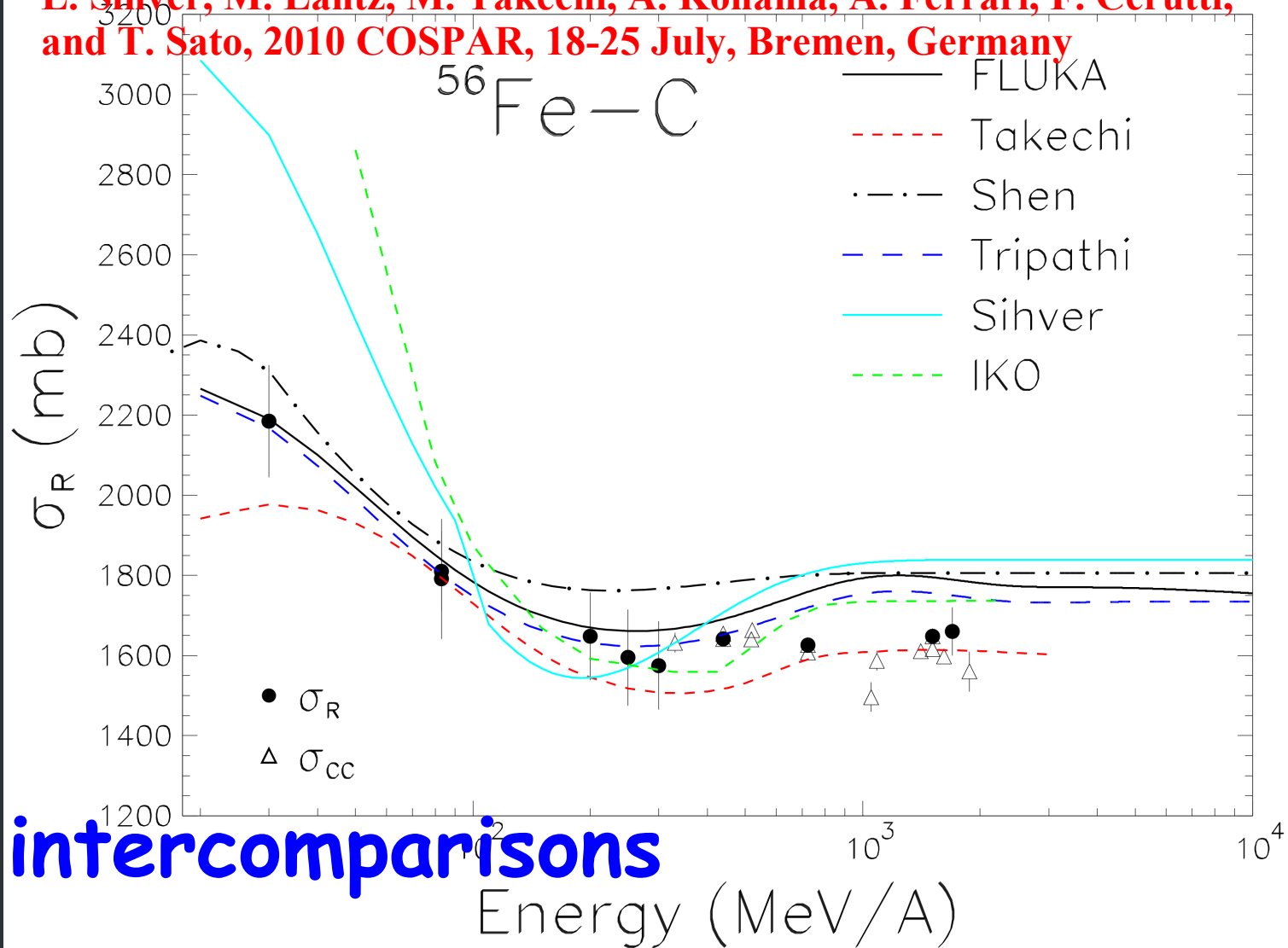


Code intercomparisons



Positive effects from the addition

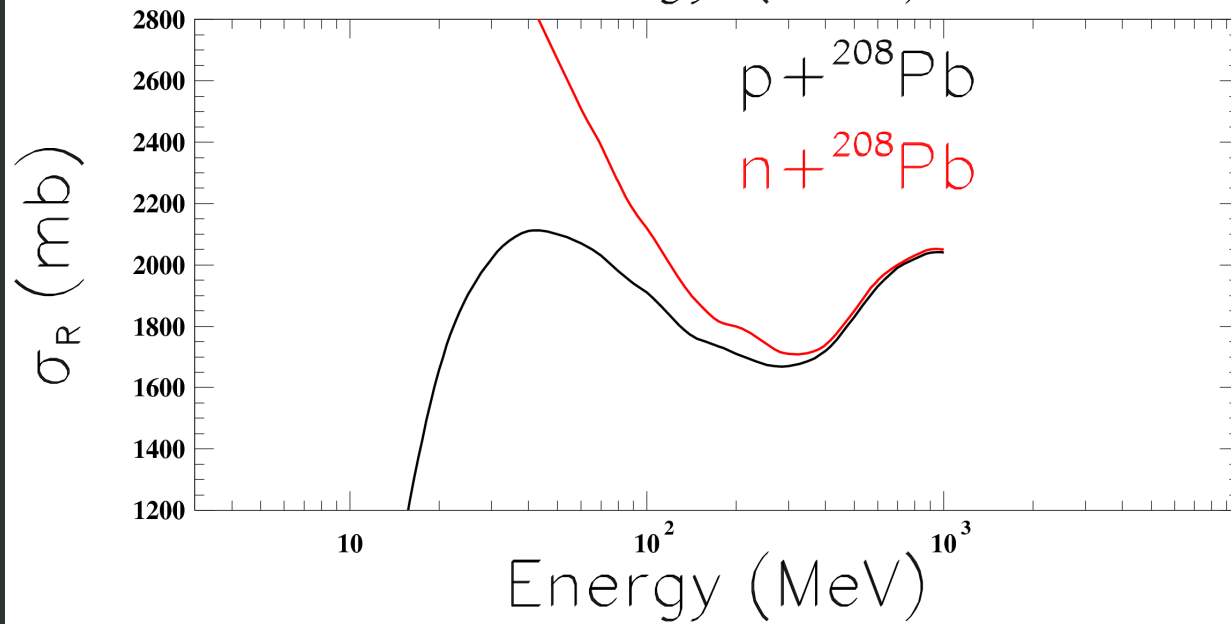
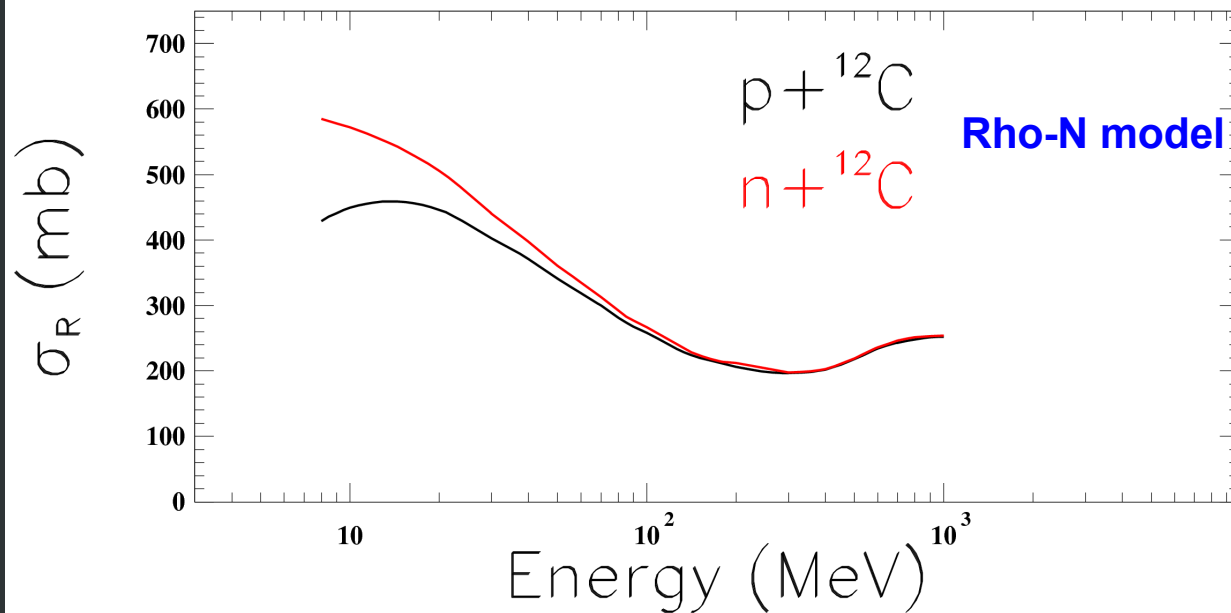
L. Sihver, M. Lantz, M. Takechi, A. Kohama, A. Ferrari, F. Cerutti,
and T. Sato, 2010 COSPAR, 18-25 July, Bremen, Germany



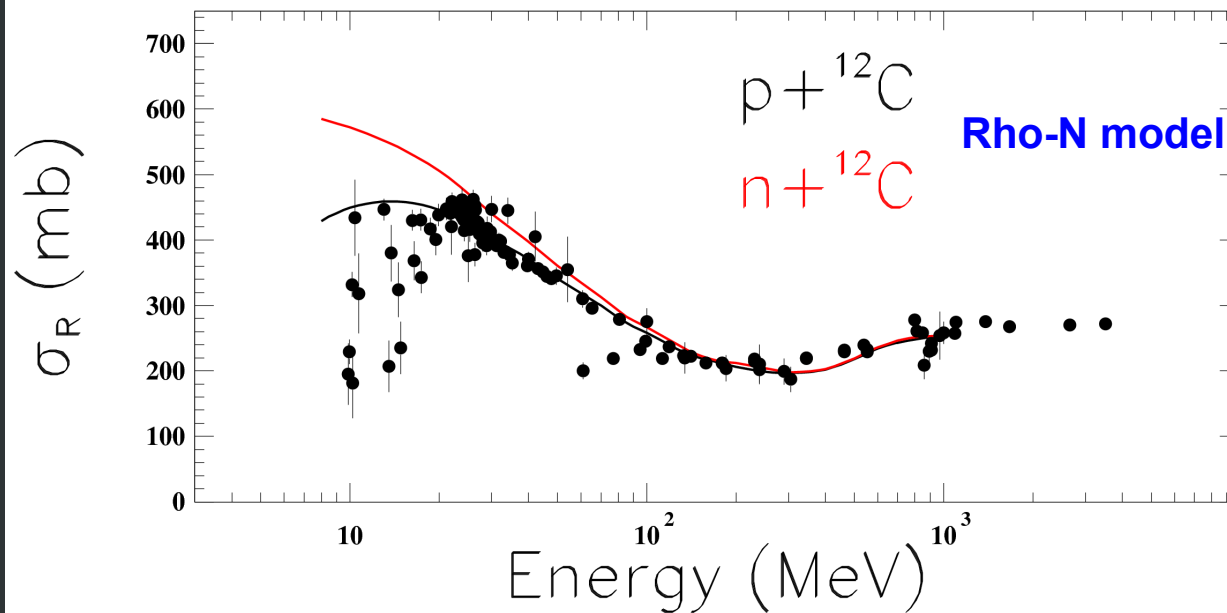
Code intercomparisons



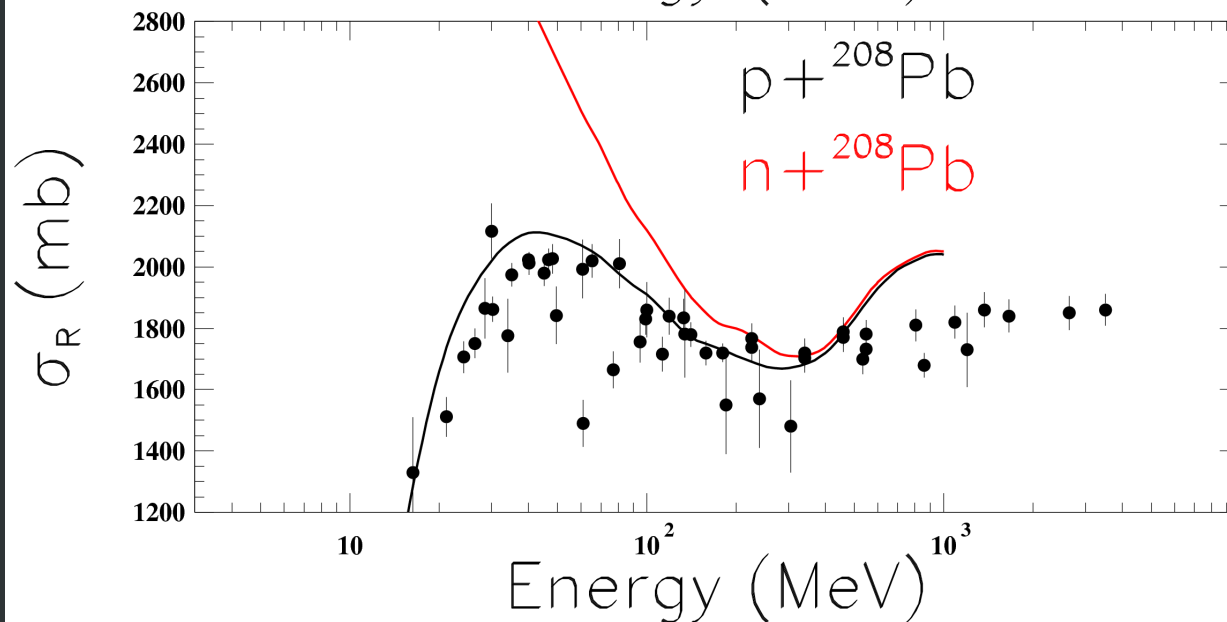
Positive effects from the addition Motivate new neutron measurements?



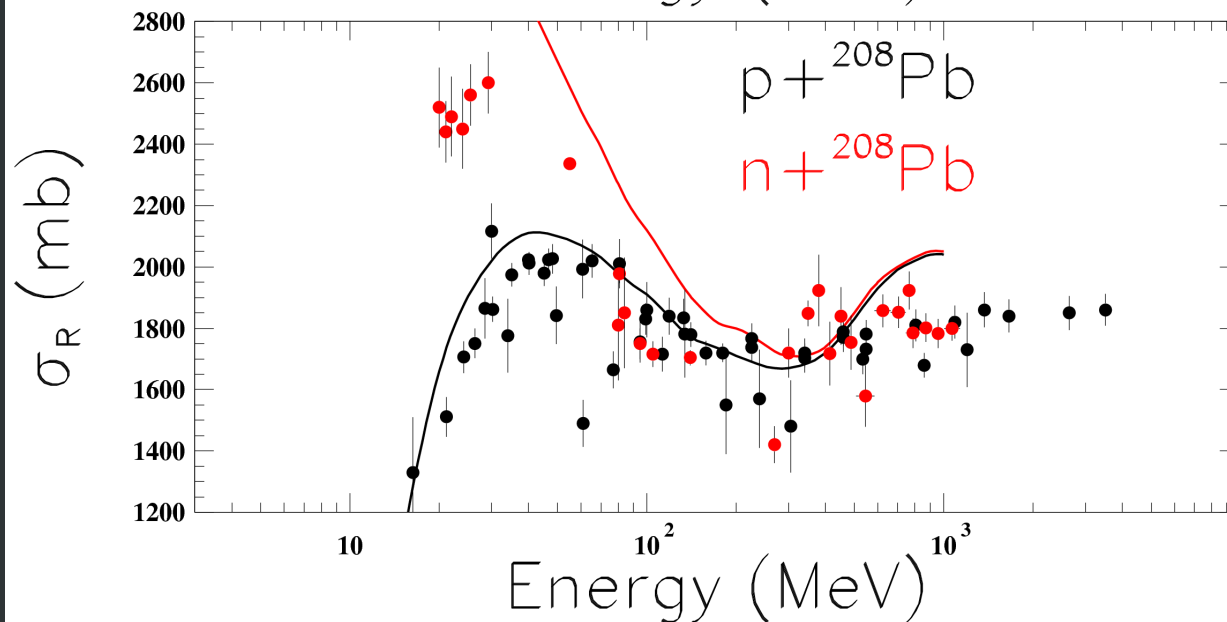
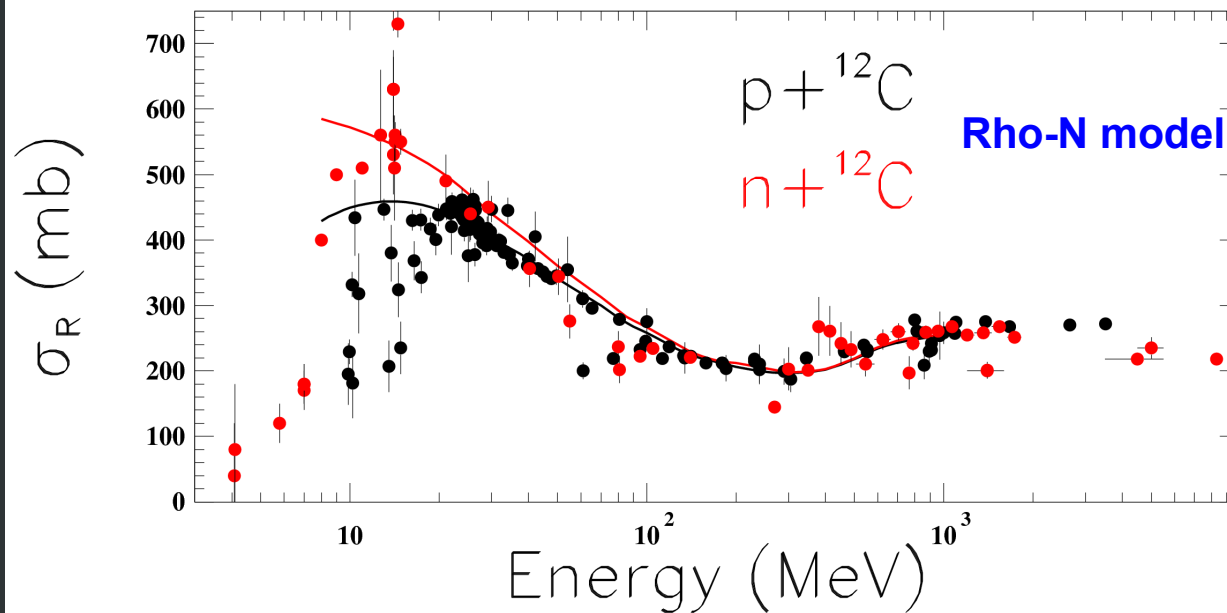
Positive effects from the addition Motivate new neutron measurements?



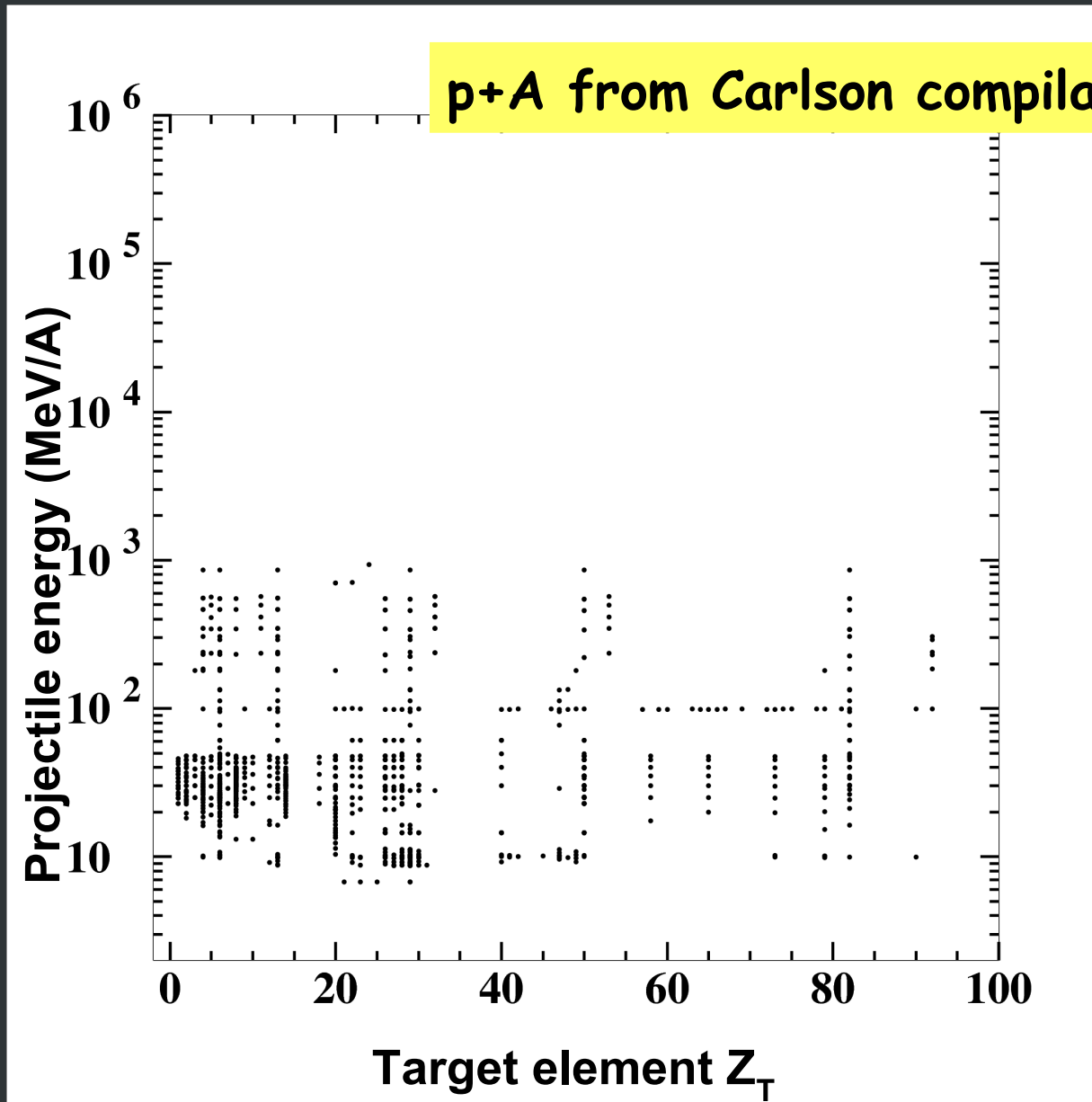
Rho-N model (Ingemarsson & Lantz (2005))



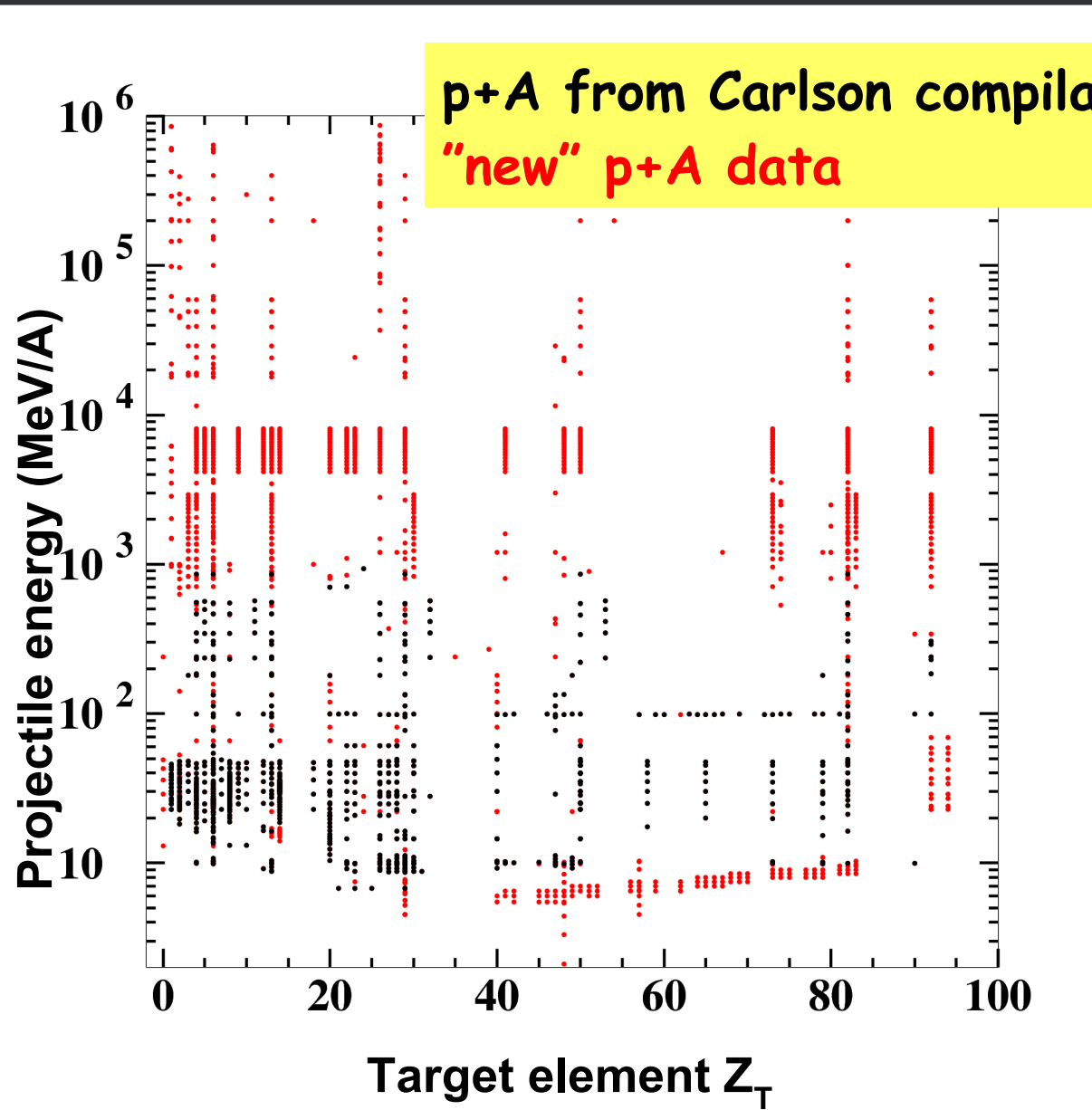
Positive effects from the addition Motivate new neutron measurements?



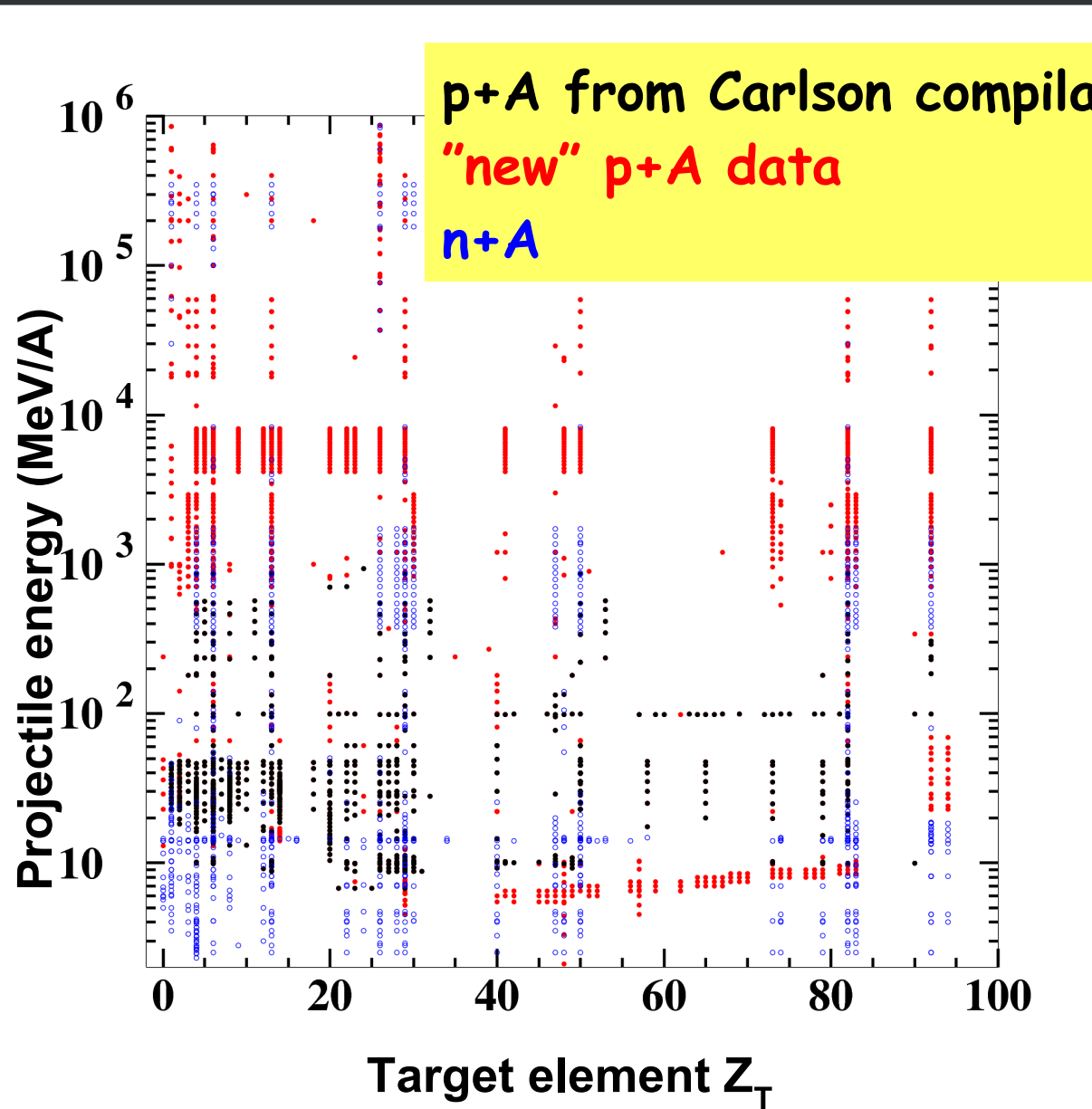
Other effects from the addition



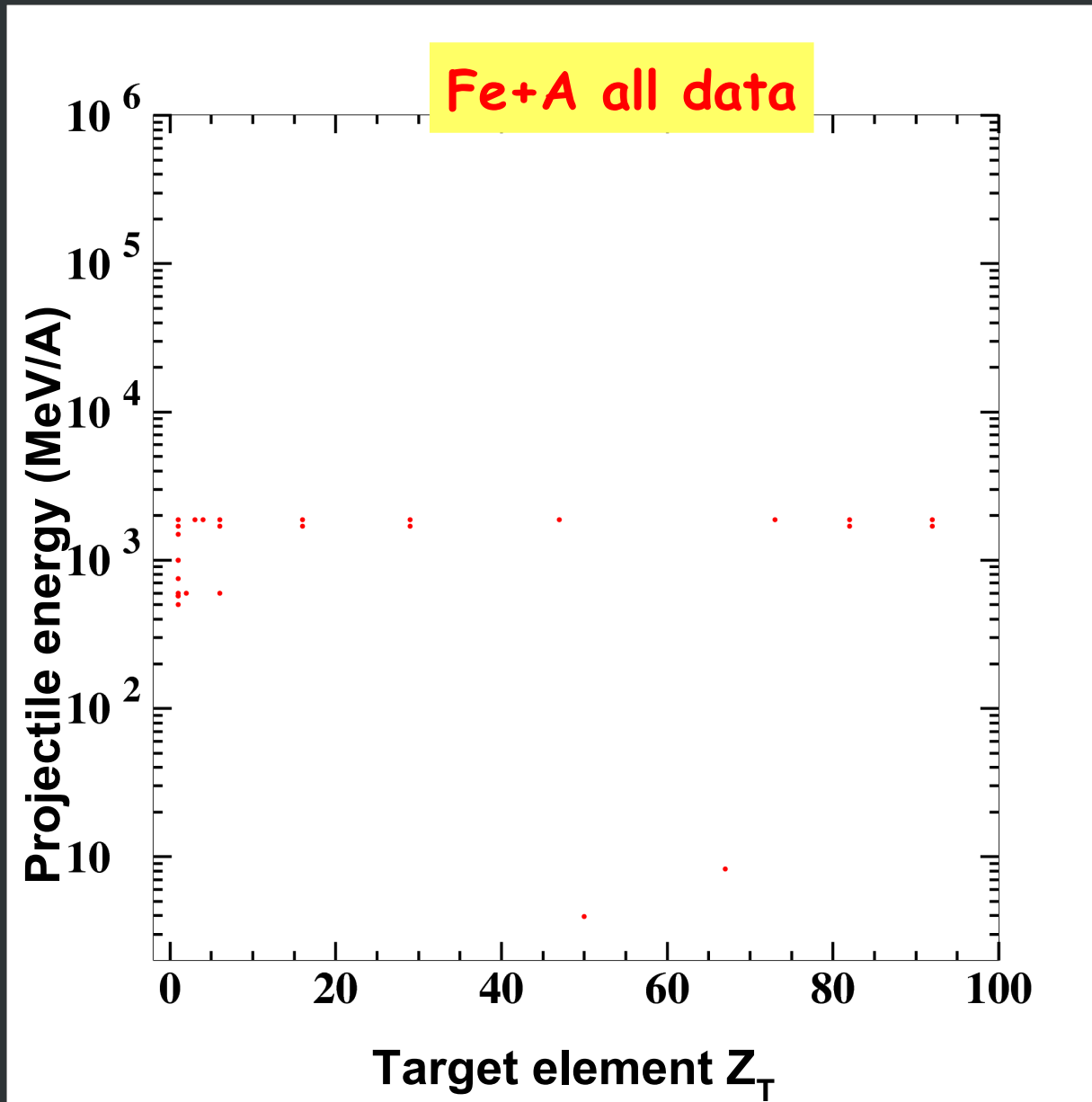
Other effects from the addition



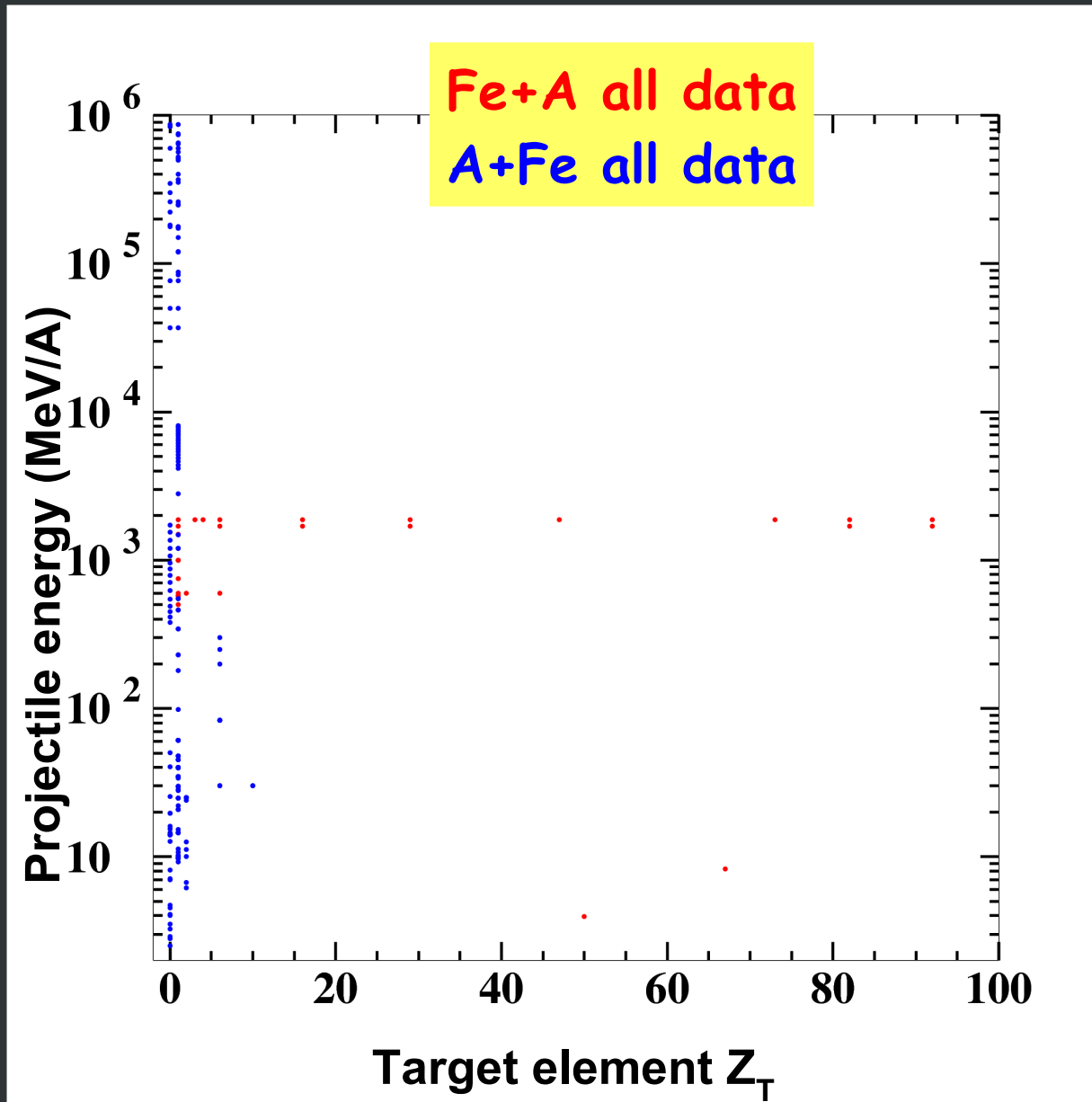
Other effects from the addition



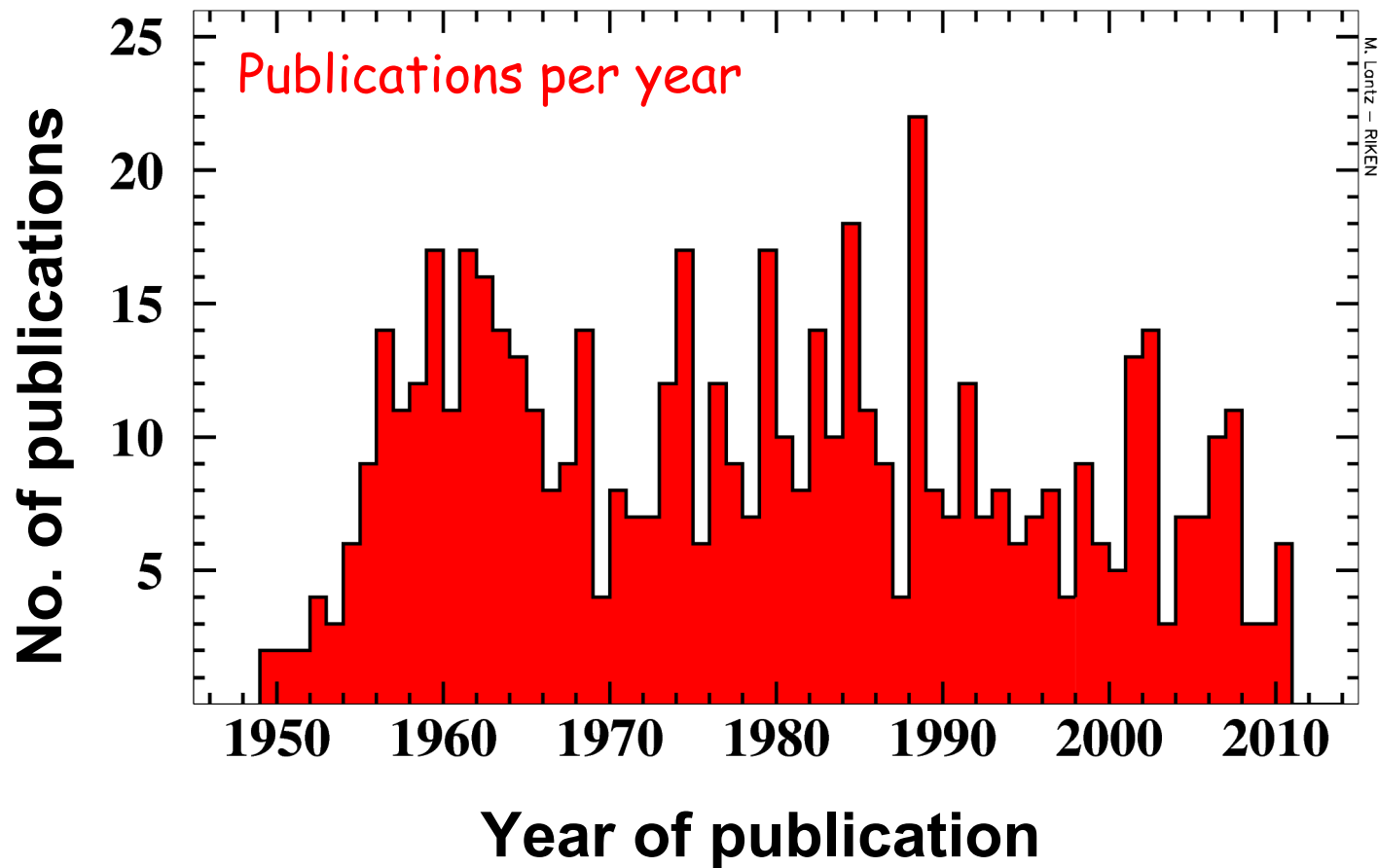
Other effects from the addition



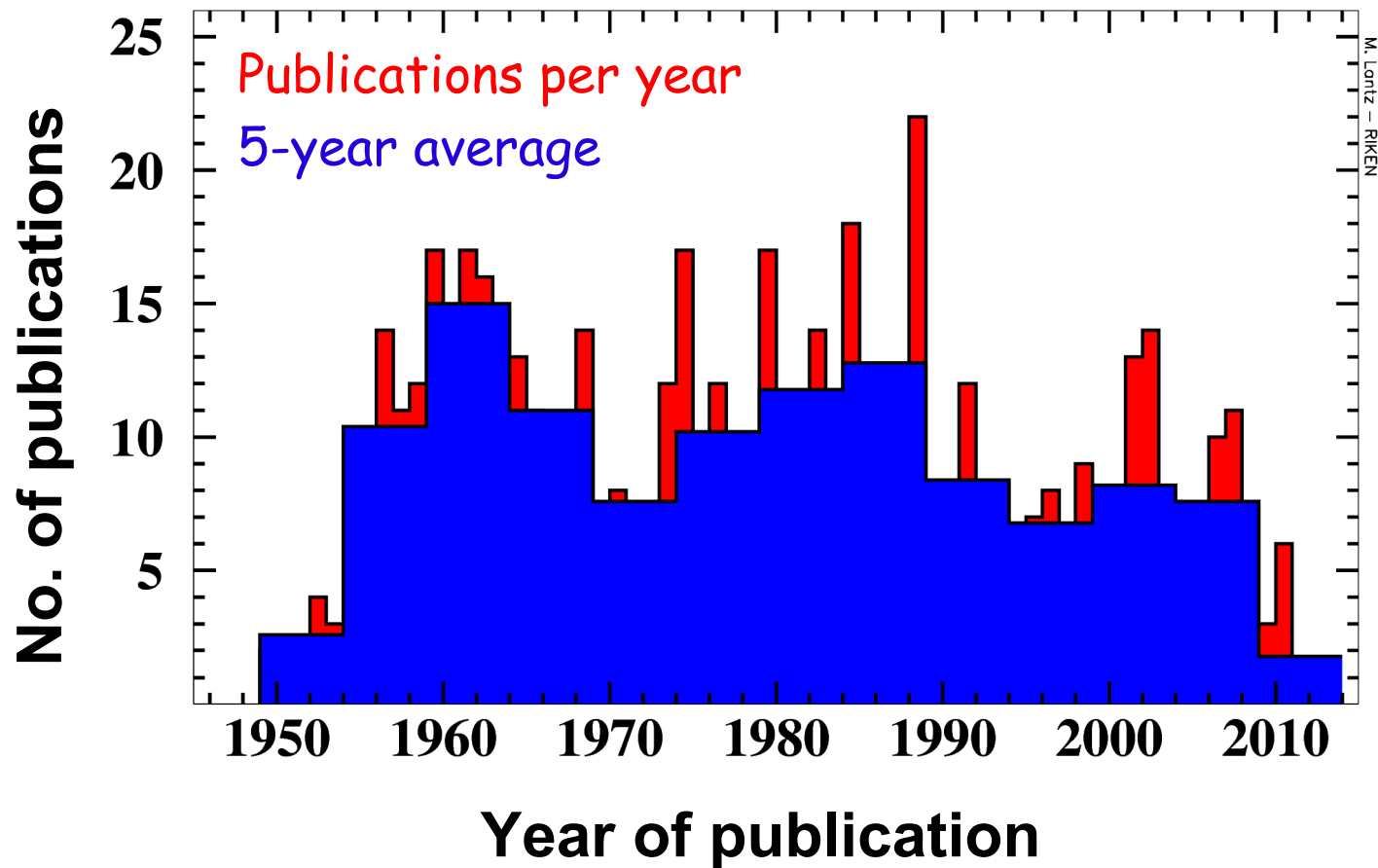
Other effects from the addition



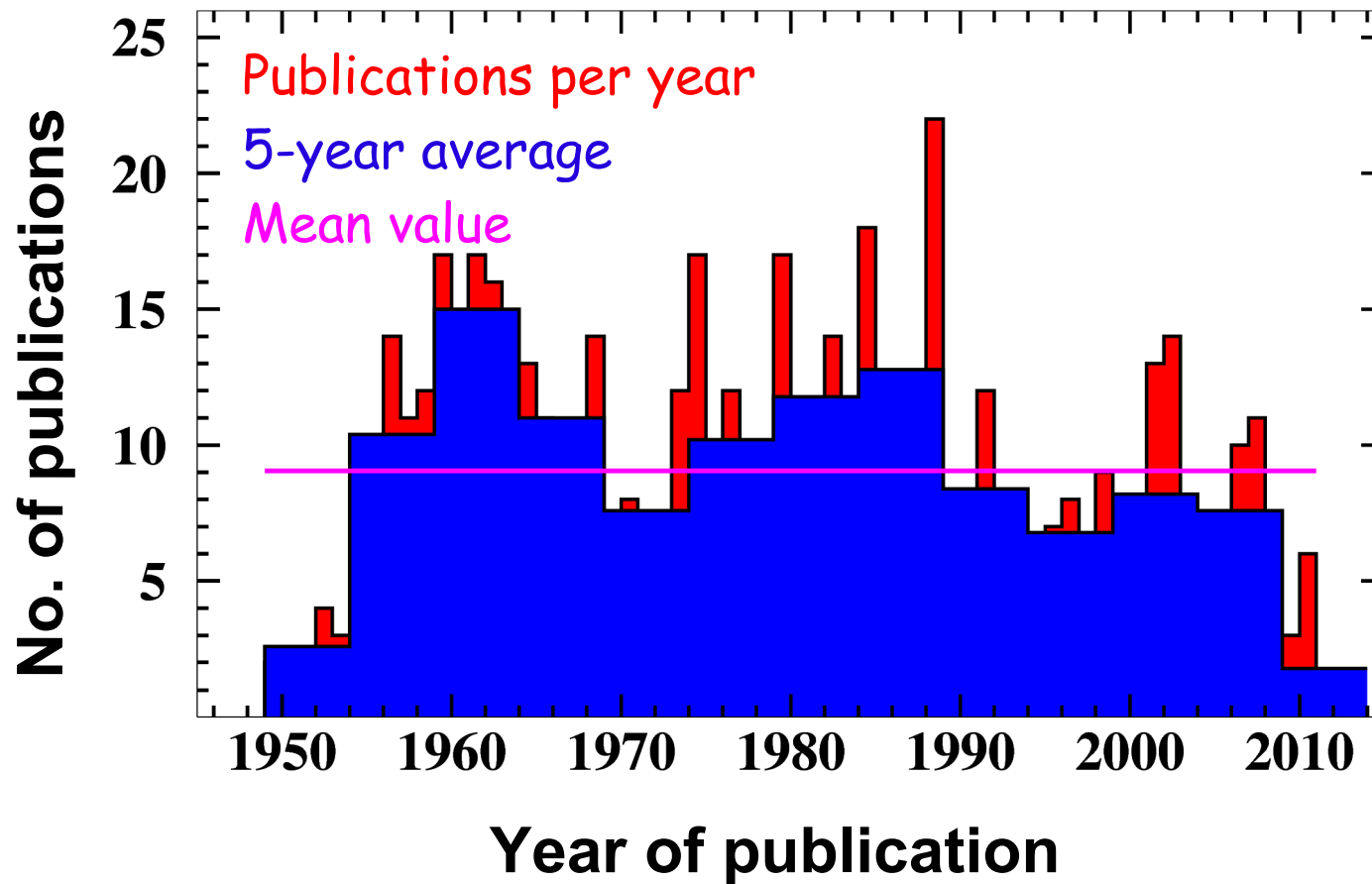
Other effects from the addiction Science history, or sociology?



Other effects from the addiction Science history, or sociology?

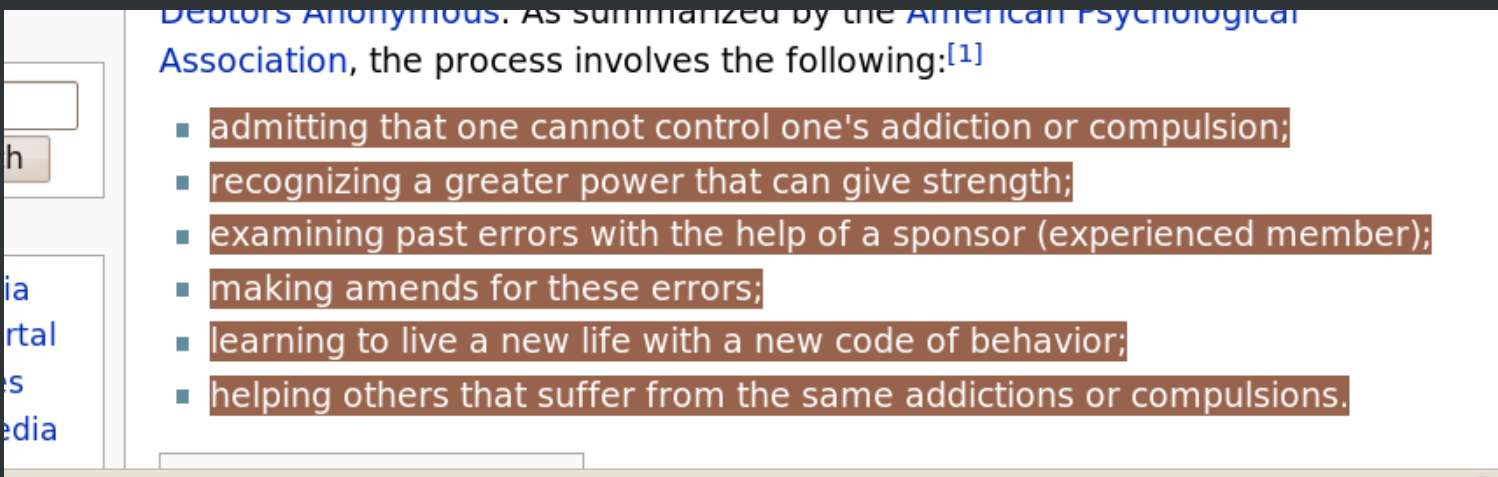


Other effects from the addiction Science history, or sociology?



A call for help

- Still looking for more data, do **You** have any?
- How would **You**, as potential user of the compilation, prefer it to look like?
- Please contact us if you have any feedback, data, or comments: Mattias.Lantz@fysast.uu.se



Debtors Anonymous. As summarized by the American Psychological Association, the process involves the following:^[1]

- admitting that one cannot control one's addiction or compulsion;
- recognizing a greater power that can give strength;
- examining past errors with the help of a sponsor (experienced member);
- making amends for these errors;
- learning to live a new life with a new code of behavior;
- helping others that suffer from the same addictions or compulsions.



Thank you for your attention!

- Acknowledgements for valuable feedback, help, and inspiration
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 - Chen Li - [Lanzhou](#)
 - Richard F. Carlson - [Redlands University](#)
 - Alfredo Ferrari - [CERN](#)
 - Grzegorz Kaminski - [JINR](#)
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